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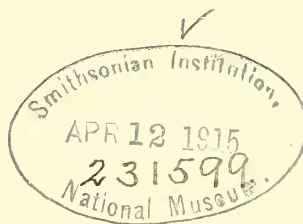
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AGE AT MATURITY OF THE PACIFIC COAST
SALMON OF THE GENUS ONCORHYNCHUS



By Charles H. Gilbert
Professor of Zoology, Stanford University

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AGE AT MATURITY OF THE PACIFIC COAST SALMON OF THE GENUS *ONCORHYNCHUS*.



By CHARLES H. GILBERT,
Professor of Zoology, Stanford University.



INTRODUCTORY.

During the past two summers (1910 and 1911) the writer has been engaged on behalf of the United States Bureau of Fisheries in determining the age at maturity of the five species of Pacific coast salmon, together with such other facts of their life history as can be inferred from the structure of their scales. The problem has a peculiar interest as concerns these species because of the fact, now sufficiently demonstrated, that all individuals perish when they have attained sexual maturity. They spawn but once and then die, whatever the age or size at which sexual maturity has been reached ^a and whatever may be their physical condition at the time of spawning. This peculiarity in their life history renders the question of their age at maturity an unusually important one, both from the scientific fish cultural and the purely economic standpoints.

Many attempts have been made to solve the problem for the two species commercially most important—the king salmon and the sockeye—usually by marking the artificially reared fry by clipping one or other of their fins before they are liberated, in the hope of recognizing the adult fish on their return at maturity. Unfortunately, these important experiments have lacked adequate supervision, and have furnished somewhat discordant and uncertain results. These have been supplemented, however, by the experiments in Tomales Bay, Cal., and in New Zealand, where fry were planted in streams not frequented by the species in question and the return of the adults was noted. Also, in the case of the sockeye, we have had as additional evidence the quadrennial increase in the Fraser River, which has been very generally accepted as demonstrating a four-year cycle for this species.

All the evidence available was considered by F. M. Chamberlain, in his highly valuable "Observations on Salmon and Trout in Alaska" (Bureau of Fisheries Document No. 627, 1907), with the resulting conclusion (p. 66):

There seems to be sufficient reason for believing four years to be the usual term of life for the sockeye and the king salmon, but experiment has pretty conclusively shown that they may mature in less time or may be retarded beyond that term.

^a With the possible exception of certain male king salmon fingerlings, which mature precociously in the streams during their first year, at a length of 3 to 7 inches. The fate of these has not as yet been determined.

This may be accepted as an adequate statement of our belief respecting these species up to the present time. It has lacked in definiteness and in detail. No conclusive evidence has been presented concerning the age of the markedly undersized fish or "grilse," which are conspicuous parts of the king salmon and sockeye runs. We have no knowledge concerning the extreme age which any species may attain, nor concerning the proportions in which different ages are represented in the spawning run. Furthermore, the question of size with relation to age has been wholly undetermined, the belief being yet widely entertained that no such relation exists, size being solely dependent on richness of feeding in the sea.

There remains to be noticed a recent attempt by Prof. J. P. McMurrich ^a to solve these problems by a consideration of scale and otolith markings. The figures of scales and otoliths presented in this paper show sufficiently that these structures present seasonal markings which when correctly interpreted will afford reliable indication of age. It is to be sincerely regretted that Prof. McMurrich's interpretations have been based on inadequate data, and these have misled him into announcing a series of conclusions so largely erroneous as to confuse rather than clarify the questions at issue. A further discussion of these matters will appear under each of the species considered below.

The present paper contains a purely preliminary statement of certain facts in the history of our salmon which can be substantiated through a study of scale structure. This method offers certain obvious advantages over that of determining the age by marking the young, although the latter method should be employed and rigidly supervised in corroboration of the former. But the scale method is of unlimited application. Any desired number of individuals can be investigated in connection with size and sex and other modifying factors. It thus becomes possible to analyze an entire salmon run into its age components, and each of these can then be the subject of further investigation and analysis. We can thus determine the range in size of each group and of the males and females separately for each age, and when definite events in the life history of the fish record themselves upon the scales—as we believe to be the case—corresponding categories can be formed and the possible effects of these events on growth and period of maturity can be determined. A very wide usefulness, therefore, attaches to this method, and for its proper elaboration discriminating study of many thousand specimens must be made.

While the method is new as regards Pacific salmon, it has been experimentally tested and fully approved by the Fisheries Board for Scotland in the case of the Atlantic salmon, and is now universally accepted as furnishing reliable data as to the age and many other facts in the life history of that fish. It has been shown to be applicable also to various species of trout, and its value has been demonstrated in fishes as widely divergent as the carp, the eel, the bass, the flounder, and the cod. Descriptions of this scale structure and its significance have appeared in a large number of papers, both scientific and popular. It will suffice here to repeat that the scale in general persists throughout life, and grows in proportion with the rest of the fish, principally by addi-

^a The life cycles of Pacific coast salmon belonging to the genus *Oncorhynchus*, as revealed by their otolith and scale markings. Transactions Royal Society of Canada, 1912.

tions around its border. At intervals there is produced at the growing edge a delicate ridge upon the surface of the scale, the successive ridges thus formed being concentric and subcircular in contour, each representing the outline of the scale at a certain period in its development. Many of these ridges are formed in the course of a year's growth, the number varying so widely in different individuals and during successive years in the history of the same individual that number alone can not be depended on to determine age. For this purpose we rely upon the fact that the fish grows at widely different rates during different seasons of the year, spring-summer being a period of rapid growth and fall-winter a season when growth is greatly retarded or almost wholly arrested. During the period of rapid growth the ridges are widely separated, while during the slow growth of fall and winter the ridges are crowded closely together, forming a dense band. Thus it comes that the surface of the scale is mapped out in a definite succession of areas, a band of widely spaced rings always followed by a band of closely crowded rings, the two together constituting a single year's growth. That irregularities occur will not be denied, and this is natural, inasmuch as growth may be checked by other causes than the purely seasonal one. Also a considerable experience is requisite for the correct interpretation in many cases, and a small residue of scales of doubtful significance has always remained. This element is too small to affect the general results, and further investigation will almost certainly eliminate the doubtful cases altogether.

SOCKEYE OR RED SALMON (*Oncorhynchus nerka*).

[Pl. I-III; fig. 14, pl. VIII; fig. 22, pl. XII.]

The sockeye, red salmon, or blueback, as it is variously known, has been assumed to mature principally if not wholly in four years, on the basis of the constant four-year periodicity in the magnitude of its run in the Fraser River. Richardson is reported as having marked young sockeye at Karluk, Alaska, and observed their return at four years on the average. Chamberlain marked young hatched from 1902 eggs and planted the marked fry in the Naha River, Alaska. The return of adults bearing the appropriate mark was reported in 1906 and 1907, and has continued to be reported for each year since that date, including the summer of 1911. If these results are accepted, individuals may even reach the age of 9 years before maturing; but this is a conclusion so at variance with other evidence and with general probability that complete corroboration is required.

Finally, on the basis of scale and otolith structure, McMurrich announces 4 years as the age of adult Fraser River sockeye and 2 years for the undersized or grilse form. But as he frankly bases his investigation upon the a priori assumption that Fraser River sockeye must be 4 years old, and interprets scale and otolith structure in accordance with that assumption, it can hardly be claimed that his conclusion adds anything to our previous knowledge. This becomes the more apparent upon an examination of his figures, which indicate that he unfortunately chose for examination certain large specimens which were in reality 5 years old and not 4. Forced by this method to make an erroneous interpretation of the central area of the scale, all his conclusions are vitiated which

deal with the sockeye, the king salmon, and the coho. Thus the sockeye grilse is a 3-year and not a 2-year fish, a fact which we learn with some relief, in view of the very large numbers of grilse which regularly make their appearance three years after each quadrennial big run in the Fraser and the small numbers which can be observed in the intervening years. For reasons which will appear later, McMurrich's initial error did not to the same extent affect his interpretation of the scales of the humpback and dog salmon.

Our knowledge of the life history of the young sockeye is founded first on the important researches of Commissioner J. P. Babcock for the Fraser River (Report Fisheries Commissioner for British Columbia, 1903), and later of Chamberlain, for certain streams in Alaska. These investigators agree that in the early spring two sizes of young sockeye may be found together in the streams on their downward migration to the sea. The smaller of these comprise fry of the year hatched from eggs of the preceding fall, and are then about $1\frac{1}{2}$ inches long. Those of larger size are yearlings, which instead of running out to sea the previous spring as fry, have remained in the lake during their first year and have grown during that time to a length of 3 or 4 inches.

The relative proportions of fry and yearling migrants in such streams as the Fraser and the Karluk are unknown. More fry have usually been captured in the fine-meshed nets employed for the purpose, but the superior strength and wariness of the larger yearlings have doubtless affected the result. It is also unknown whether in the same stream these two groups remain relatively constant in size or fluctuate widely from year to year in accordance with changing conditions of unknown nature. Chamberlain has pointed out that in the Naha River, Alaska, all the young remain in the lake during their first year, and migrate in their second spring as yearlings. It seems very probable that the chances of survival of yearling migrants is better than that of the fry, in which case a larger proportion of adults might be derived from that group, even in streams where considerable numbers migrate as fry. As will be shown below, the scales develop differently in the two groups. The history of each group can therefore be traced and the proportions which attain maturity can be determined.

In his interpretation of the sockeye scale McMurrich assumes that 13 of the 14 specimens which he examined belonged to the group which migrated as fry, the central close-ringed area of the scale having been formed during their brief life in fresh water. But, as a matter of fact, at the time when young fry migrate no scales whatever have made their appearance. In this group, therefore, the adult scales contain no record of life in lake and stream, even the innermost rings having been formed under marine or estuarial conditions. The close-ringed area which forms the center of the scale in McMurrich's specimens, as well as in the great majority of Fraser River sockeyes (pl. II, fig. 4), designates members of the second group, which have remained in their native stream or lake until their second spring. It presents, therefore, such record as we have of approximately the first year and a half of their life cycle. Plate III, figure 5, represents a scale, enlarged 40 diameters, of a yearling $3\frac{3}{4}$ inches long, taken in the Fraser River in April, 1903, by J. S. Burcham, working under instructions of Commissioner J. P. Babcock.

The scales in different yearlings captured at the same time and place differ considerably in size of scale and in the number of rings which they contain. Precisely similar variations are found in the nuclear areas of the adult scales, these being larger in some individuals than in others, and containing more numerous rings. Every variety of scale from migrating yearlings can be matched in the close-ringed centers of adult scales, both as regards actual size and in the number and arrangement of the rings. We can entertain no doubt, therefore, that the two have had an identical history. (See pl. II, fig. 4, with center of adult scale enlarged 40 diameters.)

The peripheral part of the scale seldom offers any difficulty. After life has begun in the sea, a regular alternation occurs of bands of widely spaced and of narrowly spaced rings, as shown in plate III, figure 6, the widely spaced rings representing the vigorous growth of spring and summer, the narrow rings the retarded growth of fall and winter. Finally, at the margin of the scale of the mature sockeye about to enter the Fraser are found a few widely spaced rings, indicating that the rapid growth of the summer in which maturity is attained early comes to an abrupt conclusion. This is true in the sockeye in greater degree than in other species of the genus, and may have its explanation in the earlier date at which mature sockeye discontinue feeding. All species of Pacific salmon (the steelhead is not here considered) cease to feed on entering fresh water at maturity, but the sockeye is extreme in this regard. Those bound for the Fraser are already fasting when first encountered along the Vancouver Island shore at the entrance to the Straits of Fuca, where other species are feeding greedily. The sockeyes are then over 100 miles from the mouth of the Fraser and are assuredly at that time not under the influence of fresh water. Fishermen are well acquainted with the fact that the sockeye, unlike the king salmon and the coho, are not to be taken by trolling, even when first they strike the coast.

With these facts in mind, we turn to plate II, figures 3 and 4, which represent a scale typical of a majority of the sockeyes of the Fraser River run. The nuclear area of finely crowded rings contains no record of the first winter after the eggs are laid, but represents the first summer and second winter which were spent in the lake. The broad band of widely spaced rings surrounding the nuclear area was formed in the sea and represents the second summer, thus completing the second year of the cycle. Then follow a narrow winter band of closely spaced rings and a second distinct summer band, constituting the third year of the cycle, and another winter band and the short marginal summer band of the fourth year.

While the majority of the Fraser River run are in their fourth year as shown by the evidence here adduced, a considerable number of them, including all the larger individuals, are just as evidently in their fifth year. The 4-year fish show, outside the nuclear area, three summers' growth and two winters' growth in the sea. The 5-year fish, as shown in plate VIII, figure 14, have just as distinctly, outside the nuclear area, four summers' growth and three winters' growth in the sea. As is given in a later table, there is a wide overlapping in size of the 4 and the 5 year fish, but all the smaller specimens are 4 years and all the larger are 5 years old. The specimens examined and

figured by Prof. McMurrich unfortunately were chosen from among the larger of those to be found on the cannery floor.

The great majority of the Fraser River sockeyes have scales of the type above described, the nuclear area being small, of crowded rings, and sharply set off from the widely spaced summer rings which surround them. As we have shown, these have all developed from fish which migrated seaward as yearlings. A different type is represented by plate XII, figure 22, in which it is seen that the nuclear area is much larger, the rings less closely crowded and widening gradually outward, until in extreme cases they merge almost imperceptibly with the succeeding summer rings. A scale of this type is figured by Prof. McMurrich (pl. III) and is interpreted by him as indicating a fish "which went to the sea as a yearling in the second spring after hatching." But the very reverse would seem to be the case. The large size and more widely spaced rings of the nuclear area indicate that growth in those individuals which spend their first year at sea is much more rapid than in those which remain in fresh water, and this is in accord with the few experiments which have been made with king salmon to determine that point. But more conclusive evidence of the history of these fish is found on comparing their type of scale with the scales of the humpback and dog salmon, which always migrate seaward shortly after hatching and while still in the fingerling stage. The nuclear area of humpback and dog salmon is exactly similar to the sockeye type last described, being comparatively large in size and of widely spaced rings. Furthermore, the king salmon, which migrates seaward partly as fingerlings and partly as yearlings, exhibits the same two types of scale shown by the sockeye, one with a small nuclear area of crowded rings, formed as can be demonstrated during the first year in fresh water, the other similar to the "sea type" of the humpback and dog salmon. While therefore we lack such direct demonstration as could be obtained by marking sockeye fingerlings on their seaward migration and observing on their return that the scales exhibit the "sea type" of nuclear area, there is yet sufficient evidence for the correctness of the theory to warrant us in accepting it.

The possibility of distinguishing throughout their lives those individuals which passed to sea immediately after hatching from those which migrated as yearlings has opened up a wide field of investigation, upon which we have thus far barely entered. A certain practical difficulty is encountered at the outset. In the majority of cases there is no question to which type a given scale belongs. But among those of undoubted "sea type," including humpbacks and dog salmon, as well as certain sockeyes and king salmon, there is found a tendency to the narrowing of a few of the rings immediately surrounding the nucleus, forming a sort of core to the nuclear area. (See pl. x, fig. 17.) The significance of this is in question, but we may perhaps hazard the conjecture that in such a case the individual tarried in fresh water or played back and forth on the tides for an appreciable time, during which growth was less rapid than in the majority which passed directly out to sea. Whatever the cause, this tendency to a slight central narrowing of rings of the nuclear area is of not infrequent occurrence in scales of the sea type, and is occasionally so pronounced as to simulate the smaller and least typical of what we may call for purposes of distinction the "stream nucleus." In a small proportion of

cases this may be the source of genuine doubt as to the early history of the individual and incidentally as to its age. For, if the nuclear narrowing be interpreted as indicating the first year spent in fresh water, the age will be greater by one year than if it be interpreted as the central narrowing of a large nuclear area of the "sea type." It is believed, however, that all doubt of this character can be removed by further investigation. For purposes of a preliminary discussion, like the present, as the doubtful cases are few in number, they can be omitted from consideration.

There is a fair indication—not to be taken as conclusive—that those individuals among the sockeyes which proceed to sea shortly after attaining the free swimming stage experience a mortality far in excess of those which pass to sea as yearlings, but that those of the first class which survive grow much more rapidly the first year than they would have done had they remained in fresh water. To a certain extent they seem to maintain this preponderance in size during succeeding years. In the Fraser River, as already indicated, only a very small proportion of adult fish have developed from young which sought the sea during their first year. Thus out of 625 individuals taken at random, without selection, from the cannery floor, only 35 belong to this group, while 590 had spent their first year in their native waters. So limited a number as 35 forms a wholly inadequate basis for generalizations, but it is worthy of note that 3 of these were grilse, maturing in their third year, 30 were in their fourth year, and only 2 in their fifth. If a larger series shall verify essentially the proportions here indicated it will demonstrate that early migration of the young accelerates growth and also the early coming to maturity, producing a larger proportion of grilse which mature in their third year, and a much greater preponderance of fourth to fifth year fish than occurs among those which migrate as yearlings. The increased size at the same age becomes evident on comparing the three "sea type" grilse above mentioned with "stream" grilse taken on the same date. The former were respectively 23, $23\frac{1}{2}$, $23\frac{1}{2}$ inches long and weighed $4\frac{3}{4}$ to $5\frac{1}{4}$ pounds. Sixteen grilse of the stream type taken on the same date (all that were secured) show the following lengths in inches: $17\frac{3}{4}$, 18, 18, $18\frac{1}{8}$, $18\frac{1}{2}$, $18\frac{1}{2}$, $18\frac{1}{2}$, 19, 19, $19\frac{1}{4}$, $19\frac{1}{2}$, $19\frac{1}{2}$, $19\frac{1}{2}$, 20, $20\frac{1}{2}$. Three of these, $18\frac{1}{2}$, $18\frac{1}{2}$, and $19\frac{1}{2}$ inches long weighed each $2\frac{3}{4}$ pounds. It is further noticeable that 2 of the 3 grilse of the sea type were females, while among Fraser River grilse of the stream type females are so rare that we have thus far discovered but one among over a hundred grilse examined. This is a matter, however, which may be subject to wide variation in different streams. In the Columbia River, for instance, in 1910, grilse were numerous, and males and females in approximately equal numbers.

In discussing the commercial value of a run the grilse may be omitted from consideration, as ordinarily they are few in number and so small as to have practically no value. The valuable elements of the run are fish which are maturing in their fourth or in their fifth years. It was attempted during the season of 1911 to determine the relative proportions of these two generations, their range in size, and their average weight. In order to simplify the problem as much as possible we have omitted from our list the comparatively few individuals of sea type. In 500 fish of stream type, taken at random from the cannery floor, 271 were 4-year and 229 5-year fish. Of the 271 4-year

fish, 126 were males, 145 females; of the 229 5-year fish, 129 were males, 100 females. The total number of males (255) was but slightly in excess of the total number of females (245). Among 4-year fish the females were decidedly in excess, among 5-year fish the males.

As regards weight, 113 4-year fish taken without selection aggregated 709.25 pounds with an average of 6.27; 104 5-year fish weighed 776.25 pounds, with an average of 7.46. Extremes of weight among 4-year fish were 4.75 and 8, among 5-year fish 5.75 and 8.75.

The following table gives distribution in accordance with their length of the 500 individuals of the stream type in which age was determined, the 4-year males being compared with the 5-year males, and the 4-year females with the 5-year females.^a At the time the measurements were taken the jaws in the males were seldom strongly hooked, but a preorbital elongation was apparent which accounts in part but not wholly for the greater length of males than of females. The fish were measured over the curve of the body from the end of the rostrum to the tips of the middle rays of the caudal fin. It will be noted that the range in size of the 4 and 5 year fish overlap widely, but the curves are characteristically distinct, the 5-year fish averaging at least 2 inches longer, out of a total range of 5 inches in length for each group. Examination of a larger series of individuals would unquestionably extend the limits of each group by the addition of the exceptionally large and the exceptionally small, but the table as presented doubtless gives correctly the range in size of the vast majority at the time the examination was made. It will be of great interest to compare similar curves prepared for the same river basin in successive years; also curves of the sockeye run in different basins.

FIVE HUNDRED FRASER RIVER SOCKEYES WHICH HAD MIGRATED TO SEA AS YEARLINGS, GROUPED BY SEX, AGE, AND SIZE.

Length in inches.	Males.		Females.		Length in inches.	Males.		Females.	
	4 years.	5 years.	4 years.	5 years.		4 years.	5 years.	4 years.	5 years.
21	.....	.....	.....	.....	26	21	25	2	27
21½	.....	.....	1	.....	26½	11	22	.....	15
22	.....	.....	1	.....	27	4	15	.....	12
22½	2	.....	2	.....	27½	.....	15	.....	4
23	4	.....	11	.....	28	.....	12	.....	2
23½	5	.....	19	1	28½	.....	2	.....	.....
24	13	.....	49	2	29	.....	.....	.....	.....
24½	20	4	27	3	29½	.....	1	.....	.....
25	23	13	22	13	Total.	126	129	145	100
25½	23	20	11	21					

Three-year fish, or grilse, were not included in the above table. During the summer of 1911 they were not numerous. Only a few (perhaps 3 or 4 on the average) could usually be found in each 1,000 fish brought in. It is the current belief among those who handle Fraser River sockeyes that all the grilse are male fish. As previously noted,

^a Measurements were made August 2-4, 1911, in the cannery of the Pacific American Fisheries at Bellingham, Wash. To the management of this concern we desire to express our grateful appreciation of their uniform courtesy.

all those examined by us were males, with one exception, a female with well-developed ova. Examination of the scales (see pl. I, fig. 1) shows that the final summer's growth is more extensive in grilse than in those which mature at 4 and 5 years, and the narrowing of the marginal rings to form the third winter band has often begun.

Much larger specimens than those included in the table were selected for examination in an attempt to find individuals older than 5 years. Several were found over 30 inches long, weighing 12 pounds, but all were 5-year fish. Examination of a larger number may possibly bring to light a rare individual which has not matured until its sixth year. Even this is doubtful and we assuredly do not anticipate finding older than 6-year individuals among the Fraser River sockeyes. The significance of the marking experiments of the Bureau of Fisheries in the Naha River, with the reported recovery of marked specimens up to 9 years old, remains to be determined.

If it be true, as indicated in our table, that relatively so large a proportion of Fraser River sockeyes mature in their fifth year, it may appropriately be asked how the enormously increased run every fourth year can be maintained in that river without its benefits becoming gradually distributed through five-year individuals over the intervening years. The great run of 1909 must have developed as 4-year fish from the superabundant eggs deposited by the great run of 1905. But if an almost equal proportion of those eggs should fail to mature until their fifth year, as was true in the 1911 run which we investigated, we should have expected a second great run, characterized by their relatively large size, in 1910. Such increased runs in the fifth years do not occur, and of this we have as yet no explanation to offer. There is some evidence that the fifth years of the cycle are characterized by fish of somewhat larger size than the other "off years," indicating, if true, a larger proportion of 5-year fish, but the total run is not appreciably increased. Certain it is that the fish of the big runs average smaller than those of the intermediate years. This might conceivably be explained by a limited food supply and sharper competition among the enormous schools of that year, but it is more probably due to the practical elimination of 5-year fish. Those 5-year fish present would have developed in their due proportion from the few eggs of an "off year," and would be too scattered to produce any effect among the vast hordes of 4-year olds. But these are matters for further investigation.

KING SALMON, OR CHINOOK (*Oncorhynchus tshawytscha*).

[Pl. IV-VII: fig. 15, pl. VIII: pl. IX; fig. 18, pl. X; fig. 25, pl. XIV.]

Speculation concerning the age of the king salmon (also called spring salmon, tye, Chinook salmon, Sacramento salmon) has been encouraged by the enormous range in size which is exhibited by spawning fish. Adult females have been reported as small as 5 pounds, and adult sea-run males much smaller than this, while individuals of from 80 to 100 pounds weight occasionally are seen. No answer has heretofore been given to questions concerning the total range in years represented by these various sizes, nor as to the exact relation of age and size.

A detailed experiment to determine these points was undertaken by Superintendent Hubbard of the Clackamas (Oreg.), station, in 1896. Five thousand young, hatched

from eggs of the preceding fall (1895), were marked by removing the adipose fin, and were then liberated. In 1898^a Columbia River cannery men reported the capture of some 375 of these marked fish, indicating their return in their third year. Thirty-two are reported, with details of sex and weight. Nineteen of these were females, ranging from 10 to 35 pounds; 13 were males, from 19 to 57 pounds in weight. The average for the 32 is 27.69 pounds, about 5 pounds above the average of all Columbia River salmon of this species.

The following year^b between 40 and 50 were reported, the average weight said to be nearly 10 pounds greater than of those taken in 1898. And in 1900, by offering a small reward for marks saved and sent in, the Oregon commissioner received 72, with no indication of weight. No further record of the capture of marked fish is contained in the Oregon reports. According to this experiment, it would appear that both males and females may mature in their third year, and that very large fish (57 pounds) may appear among those returning thus early. These results have been accepted by Rutter and others, the evidence appearing on its face unimpeachable, but they are so wholly at variance with results obtained through a study of the scales that we have scrutinized the records with some care. Certain minor inaccuracies are obvious, but the dates are well attested, and the only criticism which seems pertinent is that the commissioner apparently relied wholly on reports from the canneries, and did not personally inspect any of those specimens reported in 1898 and 1899.

Other marking experiments on the Columbia River, made by the Washington Commission at Kalama and Chinook, indicate 4 and 5 years as the age of returning fish, none being recorded in the third year. In the well-known planting experiments in Tomales Bay, Cal., and in New Zealand, both of which resulted in establishing spawning runs in streams which hitherto had not possessed them, no run was reported until the fourth year. In view of these facts and others, we must hold in question the report of the Oregon experiment of a considerable return in the third year of both males and females of large size, in spite of a certain appearance of conclusiveness in the report itself.

The history of the king salmon is known principally from the work of Rutter and Scofield on the Sacramento River, and of Chamberlain in Alaska. The fact is well attested that large numbers of fry pass into salt water in spring or early summer as soon as possible after the absorption of the yolk. Many others, but in unknown proportion, remain behind in the streams and migrate the following spring as yearlings. Whether any of these, which have been somewhat unfortunately termed "summer residents," pass out during the late summer or on the high water of the fall remains unknown, but many if not all of them remain during the following winter. The center of the king salmon scale, which records their early history, is subject to more variation than in the sockeye, and will require longer investigation in connection with young salmon of known history.

^a Sixth Annual Report Fish and Game Protector of State of Oregon, 1898, p. 48.

^b Annual Report Department of Fisheries, State of Oregon, for 1899 (1900), p. 15.

In general, king salmon scales exhibit the same two types characteristic of the sockeye—a stream type, with close-ringed nuclear area, sharply set off from the enveloping wide-ringed summer band (pl. iv, fig. 7), and a sea type, of large nuclear area, with less crowded rings, which widen outwardly and usually pass gradually into the rings of the second summer (pl. vii, fig. 13). The nuclear area of the close-ringed stream type agrees with the entire scale of a yearling on its seaward migration in its second spring, and can be safely so interpreted. The nuclear area of the sea type is here interpreted as in the sockeye, as indicative of an early passing to salt water on the part of those individuals which migrate as young fry. A more extended inquiry into this matter must be made before offering data with full conclusiveness, but it may be offered in evidence that young king salmon about 4 inches long taken in Puget Sound in mid-summer exhibited the wide-ringed sea type and were in their first year (pl. vii, fig. 12). It may also be noted that on examining a series of larger king salmon ($9\frac{1}{2}$ to $17\frac{1}{2}$ inches long) taken in late summer in Puget Sound, all were found to be in their second year, the smaller individuals ($9\frac{1}{2}$ to $11\frac{1}{2}$ inches) exhibiting the stream type of nucleus (pl. iv, fig. 7), and the larger members of the series ($13\frac{1}{2}$ to $17\frac{1}{2}$ inches) the sea type (pl. vii, fig. 13).

Conspicuous in every spawning run of king salmon are the numerous undersized males, known locally as grilse, jack salmon, or sachems. Two theories have been held regarding these, according to which they have been considered either stunted individuals of equal age with the larger salmon, or younger fish which have matured precociously. The theory of precocious development has had wider currency of late, and is in entire agreement with the evidence from the scales, according to which the individuals are always in their second or third year. The mature second-year fish are smaller than those in their third year, and are usually little in evidence, as they escape readily through the meshes of the nets. None which were mature at this age have been taken by us in Puget Sound. But on the Columbia River, a considerable series of mature males in their second year, 9 to $18\frac{1}{2}$ inches long, were secured from the seines and fish wheels. It will be noted that this range in size agrees with that already given for immature second-year fish from Puget Sound. It is further significant that in the Columbia River series, also, the smaller individuals, 9 and $9\frac{1}{4}$ inches long, are of the stream type, and the larger, 13 to $18\frac{1}{2}$ inches, are of the sea type.

The larger grilse (19 to 26 inches) are in their third year (see pl. iv, fig. 8; pl. vii, fig. 11), and among them, again, the smaller individuals of the series are preponderatingly fish of stream type and the larger of sea type. But in the third-year fish there is more overlapping of the two types, as though subsequent inequalities in growth had partially concealed the initial advantage secured by those which had early sought the sea. This is a question which merits further investigation on a much larger series than has thus far been examined.

From salt water in Puget Sound we have secured immature third-year fish, both males and females, and also matured third-year males, taken by purse seines from the same school, and both feeding voraciously and equally on small sand lance and young

herring. There was no difference in size between the mature and the immature individuals, nor could they be externally distinguished, unless by a certain distention of the abdomen in mature specimens, due to the developed testes. It became evident from our observations: (1) That a very small proportion of the males of a given year develop precociously; (2) that precocity is apparently not caused by the influence of peculiar external conditions operating upon the individuals thus affected, but by some unknown factor; (3) that precocious development does not stunt the growth. No mature female king salmon less than 4 years old have thus far been encountered.

The commercially valuable portion of the king salmon run consists mainly of 4 and 5 year fish, with less frequent 6-year individuals. Plate v, figure 9; plate x, figure 18; and plate vi, figure 10, represent these three ages. On the Columbia River they are roughly grouped at the canneries as "half salmon" and "full salmon." The half salmon consist very largely of 4-year individuals and the full salmon those 5 and 6 years old, although there is a certain amount of overlapping, as in the sockeye. The 4-year fish include more females than males, and the 6-year fish are males in even greater proportion. It is thus seen that the females are much more uniform in the age at which they mature than are the males, being practically limited to their fourth and fifth years, while males may develop precociously at any age before the fourth year, or may be retarded beyond the usual period. A single male, weighing 67 pounds, observed by Mr. N. B. Scofield in the Sacramento River, was in its seventh year. None larger than this have been examined, although such are known to occur, so the total range of the species may even include 8 years. Anything beyond seven is problematical and beyond eight must be considered highly improbable.

Among the king salmon taken by purse seines in Puget Sound and those taken by trolling in the salt water of Monterey Bay, Cal., are found 4-year-old male and female individuals which are mature, and others of the same size and age which show no activity of the gonads and would not mature until a later year. The same is true of the 5-year-old fish, but the undeveloped individuals of this age are more largely males. It seems evident that the maturing individuals feed together in the same schools with those which are undeveloped and become segregated only when the period arrives for them to seek their spawning stream.

Prof. McMurrich announces, in the recent paper already referred to, that scale and otolith structure indicate mature king salmon to be always 4 years old and the grilse 2 years old. Such a conclusion is on its face highly peculiar and improbable. That certain males should mature in their second year as grilse and all others unanimously pass their third year without precocious development would be highly remarkable. Fully as improbable would be the corollary as regards size in relation to age. As is well known, the larger grilse equal or very slightly exceed the smaller salmon of the regular 4-year series. Prof. McMurrich's contention is again based on his erroneous interpretation of the nuclear area of the scale, taken in connection with the very limited amount of material which he examined. Plate v of his paper indicates a typical 5-year scale of the stream type, the nuclear portion which he designates fresh-water being

correctly so interpreted, but representing the first year and a half of the life cycle and not the first few months only. Plate VI, figure 1, is also a 5-year fish of similar type. Plate VII represents, however, a 4-year scale, the second summer showing an "intercalated check" wholly similar to that characterizing the sockeye scale represented on plate II. But whereas the sockeye scale presents three winter bands outside the "intercalated check," the king salmon scale presents but two, hence the necessity for the author's interpretation of the same structure in two opposite ways, in order that both may appear 4 years old. As already indicated, the sockeye scale presents five years' growth and the king salmon four.

We shall not here enter upon a detailed discussion of accessory bands formed by checks in growth during the summer, especially during the first summer in the sea. Such have been demonstrated by Johnston to occur in the Atlantic salmon and are abundantly represented in any series of Pacific salmon or steelhead scales. Their true nature can usually be recognized without difficulty—as in the specific cases mentioned—by the proportion of the bands in which they occur and often by a wide variation in their appearance in different scales from the same fish. Occasionally, however, they so closely simulate genuine winter bands as to occasion some difficulty and doubt, and may then constitute one of the more troublesome features in the interpretation of large series of scales. But the proportion of doubtful cases is very small and such can be eliminated from the series without danger of affecting disastrously the results.

McMurrich's plate VI, figure 2, represents a grilse in its third year. Here the nuclear area of the scale is abnormal and does not give satisfactorily the history of the first year. Other scales from the same fish would have given this in all detail. But we have to do apparently with a fish of stream type, which spent its third winter (marked second winter) in the sea, and was therefore toward the close of its third year. Its length (approximately 20 inches) is that which we have found uniformly characteristic of third-year grilse of stream type.

SILVER SALMON, OR COHO (*Oncorhynchus kisutch*).

[Pl. XI; fig. 21, pl. XII.]

The coho agrees with the sockeye and king salmon in having a dual habit during its first year. Certain of the young migrate to sea as soon as free-swimming, others, in unknown proportion, remain in the stream until their second spring. Fingerlings are present in all streams visited by this species throughout the summer, fall, and winter of the first year. If a seaward migration occurs in the fall, it has so far not been demonstrated. In the latitude of San Francisco yearlings are very numerous in all the smaller streams as late as March and April, and are often caught by trout fishermen during the early spring months. They remain in evidence several weeks after the appearance of the fry of the year, and may then be 3 to 4½ inches long, being of the same size and general appearance as yearlings artificially reared in aquaria. Rather suddenly, on some spring freshet, they disappear from the stream. Some in their downward migration are often left stranded in overflow pools along the lower course of the stream.

A scale taken from a migrating yearling (pl. XI, fig. 19) is entirely similar to those of the stream type in the case of the sockeye and king salmon. A few widely spaced rings in the center, representing the late spring or early summer growth of the fry, are followed by closely crowded rings of fall and winter. The outermost of these are often very slender and broken. The number of rings formed during the first year varies widely, perhaps from 10 to 25, the larger number being found in general in individuals of larger growth. In many migrating yearlings the more rapid growth of the new year is apparent around the edge of the winter band (pl. XI, fig. 19), but the rings thus formed in the stream are not nearly so wide as those formed during the same season after reaching the sea. There is thus, surrounding the first year's growth, often an intermediate zone which, together with the surrounding band of very widely spaced rings, represents the second summer's growth. (Pl. XI, fig. 20.) The outer rings of the intermediate zone may even be narrowed, as though a check to growth was experienced at the migrating period. Such an intermediate zone is by no means of universal occurrence.

The further fate of the stream type yearlings is well shown in a series secured in Puget Sound in the month of August, 1910 (pl. XI, fig. 20). These range in size from 6 to 14 inches and wholly parallel the series of yearling king salmon of stream type, $9\frac{1}{2}$ to $11\frac{1}{2}$ inches, with which they were found associated. As they were taken with purse seine in the open sound, the greater number of individuals were sexually undeveloped, but a few males were developed precociously. The precocious males later join the spawning run and have been found associated with it.

We are unable to give any satisfactory account of the fry which run to sea soon after hatching. Chamberlain has reported these in Alaska waters as more numerous than those which descend as yearlings. By analogy we should expect the same to be the case in Puget Sound and California. But neither among the yearlings of Puget Sound nor the adults of this and other regions do we find scales of the sea type in any considerable numbers. Three alternatives seem to confront us. Either (1) the young do not proceed to sea as fry in the southern part of the range of the species, or (2) the fry do not survive in salt water, or (3) unlike the sockeye and king salmon there is no difference in growth during the first year between those which proceed to sea and those which remain in the streams. As bearing on this last point it must be stated that a very few individuals of undoubted sea type have been examined. The matter is one in need of complete investigation. We are of the opinion that the spawning run in Puget Sound and in California is composed of those individuals which spent their first year in the streams, with exceptions so few as to possess no practical significance.

The spawning run has been examined by us in numerous individuals covering the range in size from 17 to $30\frac{1}{4}$ inches. All of these have been fish in their third year, the scale being shown in plate XII, figure 21. The closely crowded nuclear area represents here as elsewhere the first year and a half spent in fresh water. Outside this are seen the parts representative of the life spent in the sea, consisting of the bands of the second summer, the third winter, and the third summer. Larger specimens should be

examined than any to which we have had access in search of 4-year-old individuals, but such may not be found.

Experimental evidence is thus far largely lacking in Pacific salmon to corroborate inferences we draw from scale structure. But in the coho we have one piece of evidence conclusive as far as it goes. In the midwinter of 1910-11, with the assistance of Superintendent Frank A. Shebley and Mr. W. H. Rich, we marked a certain number of yearlings in Scotts Creek, Santa Cruz County, Cal., by excising both ventral fins. In the spawning run of the winter of 1911-12 several of these returned to the same stream as mature male grilse, with scales clearly in agreement with their known age, having formed a single summer band outside the close-ringed nuclear area and a marginal narrowing for the fall growth. Full-grown fish differ from these only in having completed the winter band and one additional summer band. A more detailed account of this experiment will be given later.

Prof. McMurrich announces the coho adult to be 2 years old. He has here again underestimated by one year the significance of the nuclear area.

DOG SALMON (*Oncorhynchus keta*).

[Pl. XIII; fig. 26, pl. XIV; pl. XV and XVI.]

Less is known of the life history of the dog salmon than of any of the species thus far considered. Our knowledge of the young is entirely due to Chamberlain, who secured them on their seaward migration as fry, some with remnants of the yolk still attached. They were not associated with larger individuals which could be considered yearlings. As stated by Chamberlain, "records of the occurrence of larger individuals in streams have not been authenticated, and, so far as known, all leave the fresh water as soon as they are able to swim." Records of yearling dog salmon have been made by the writer and by others in the streams of Washington, Oregon, and California, but all such have been founded on incorrect identification of the coho yearlings.

At the time of the seaward migration of the fry no scales have been formed. It is therefore obvious that even the inner rings of the nuclear area give the history of life in the sea and not in the fresh water.

In late April, 1911, we found the fry of this species about $1\frac{1}{2}$ inches long, very numerous about the wharves and shores at Seattle, vigorously feeding on ostracods to the exclusion of other food. In midsummer, fingerlings are to be seen abundantly in the Puget Sound traps. In common with the young of other species they pass along the lead and into the heart of the trap, where they remain until forced to pass through the coarse meshes of the webbing.

The fingerlings of the dog salmon are then conspicuous among the others by their slender, graceful form, the dark blue of the back and the conspicuous black margins of the tail. Plate XIII, figure 23, represents the scale of such a specimen, 6 inches long, taken August 2, 1909, from a trap in the Gulf of Georgia. It will be noted that the rings are widely spaced, indicating much more vigorous growth than is commonly shown by such young of other species as spend their first summer in fresh water. The rings are

slightly narrowed from the center outward to about the twelfth, the outer rings showing again a decided widening. The significance of this midsummer check in growth during the first year is unknown. It is frequently wholly absent, may be present as a bare trace, or may become so well marked as to simulate the nuclear area of an individual of other species which spent its first year in the stream.

But little is known concerning the dog salmon in their second year. Fine-meshed purse seines in Puget Sound, which take so many 2-year-old coho and king salmon, are said now and again to capture dog salmon also, but none have been seen by us. A single mature male in its second year, 21 inches long, was secured at Bellingham August 3, 1910. As the habit of the species is to mature about equally during the third and the fourth years, this young male is properly to be designated a "grilse," precociously developed a year in advance. Plate XIII, figure 24, presents the scale of this specimen. The run of dog salmon has not been adequately observed, as it occurs late in the fall, when most investigators have left the field. Examination of a larger series may well show that precocious individuals (grilse) are as numerous in this species as in the others thus far considered. Whether females as well as males mature in the second year remains to be ascertained.

The series examined by the writer, exclusive of the fingerling and the grilse given above, consists of 58 mature individuals obtained at Bellingham August 2 and 3, 1910, ranging in length from 23 to 35¼ inches. They are so distributed as completely to cover this range in size. From the following table it will appear that the spawning fish are almost equally in their third and in their fourth years; or if there be any preference it is in favor of the third year. The two years overlap from the 26th to the 30th inches, inclusive, a size which seems to include the greater number of males in their third year and of females in their fourth. But the limited number of examples investigated is inadequate to decide this point. A single large male, 35¼ inches long, the largest specimen secured, was in its fifth year.

DISTRIBUTION OF MALES AND FEMALES, BY AGE AND SIZE, IN A NUMBER OF DOG SALMON, CHOSEN AT RANDOM.

Length in inches.	Third year.		Fourth year.		Fifth year.	
	Male.	Female.	Male.	Female.	Male.	Female.
23	1	3				
24	1	0				
25	2	4				
26	5	2	2	0		
27	3	0	0	4		
28	2	0	3	4		
29	5	1	2	1		
30	2	0	2	0		
31			4	0		
32			1	0		
33			3	0		
35					1	0
Total . . .	21	10	17	9	1	0

AGES AND LENGTHS OF A NUMBER OF DOG SALMON, TAKEN AT RANDOM WITHOUT SELECTION.

Years.	Length in inches.											
First.....	6											
Second.....		21										
Third.....			23 $\frac{3}{4}$	23 $\frac{1}{2}$	23 $\frac{1}{2}$	23 $\frac{3}{4}$	24	25	25	25	25 $\frac{1}{4}$	25 $\frac{3}{4}$
Fourth.....												
Fifth.....												

Years.	Length in inches.											
First.....												
Second.....												
Third.....	26	26	26	26 $\frac{1}{4}$	26 $\frac{1}{4}$	26 $\frac{1}{2}$	26 $\frac{1}{2}$	27 $\frac{1}{4}$	27 $\frac{1}{4}$	27 $\frac{1}{2}$		
Fourth.....			26		26 $\frac{1}{4}$					27 $\frac{1}{2}$	27 $\frac{1}{2}$	27 $\frac{1}{2}$
Fifth.....												

Years.	Length in inches.											
First.....												
Second.....												
Third.....												
Fourth.....	28	28	28	28 $\frac{1}{4}$	28 $\frac{1}{4}$	28 $\frac{1}{2}$	28 $\frac{1}{2}$	29	29	29 $\frac{1}{2}$	29 $\frac{1}{2}$	29 $\frac{1}{2}$
Fifth.....												

Years.	Length in inches.											
First.....												
Second.....												
Third.....												
Fourth.....	29 $\frac{1}{4}$	30	30 $\frac{1}{2}$									
Fifth.....	29 $\frac{3}{4}$		30 $\frac{1}{2}$	30 $\frac{3}{4}$	31 $\frac{1}{4}$	31 $\frac{1}{2}$	31 $\frac{3}{4}$	31 $\frac{3}{4}$	32 $\frac{1}{4}$	33	33 $\frac{1}{2}$	33 $\frac{1}{2}$
												35 $\frac{1}{4}$

In the above table fractions of inches are included with the whole numbers. While the number of individuals under consideration is too limited for safe generalization, it may yet be noted that both third and fourth year females average distinctly smaller than the males of their own age.

In plate xiv, figure 26, and plate xv and xvi, figures 27 and 28, are presented scales respectively of 3, 4, and 5 year fish. The scales of the dog salmon are broader than in any other species, the rings being approximately circular, or even broader than long. The nuclear area is always large, as in the sea type generally, comprising roughly half the diameter of the scale in 2-year-olds. The central portion of the nuclear area is usually of the open wide-ringed type, the outer portion dense (especially so laterally) and ending in a perfectly defined margin, with abrupt transition to the summer growth which follows. Considerable variation is found in the outer half of the nuclear area, but seldom any which could cause confusion. The size of the area is little variable. Only in cases where it presents a double outer band can any question arise. A slight narrowing of rings in the middle of the nuclear area is not infrequently present. Occasionally this is emphasized until the median and the marginal nuclear bands are about equal in development. In such cases irregularities and fusions can usually be found, and the size of the total nuclear area and the subsequent growths can be relied on to determine.

There is usually no narrowing just outside the nucleus to form a "core," but this may be present in a faint form, or occasionally be more pronounced.

Subsequent years' growths are usually about equal, the well-formed winter bands about equally spaced and very strongly marked. Occasional exceptions occur, in which the second summer's growth has been unusually wide and the third summer's growth much less so, with the result that the second and third winter bands are more closely apposed than usual. Such cases must be distinguished from others in which a double second winter band occurs, or an "intercalated check," during the latter part of the summer. In instances of the latter class there are usually irregularities in the development of the redundant band in different scales, also fusions of the two bands here and there. There is also a lack of any very sudden break or change in character of the rings outside a redundant band, and no unconformity in the rings, characters which very generally accompany the new year's growth.

At the 1st of August, when our series of scales were taken, the rings of the outer summer zone had in all cases begun to narrow into the winter band. The great thickness of the winter bands in this species may be in part thus explained. They may represent more than half the year's growth, beginning perhaps in July and continuing until the new year's growth commences at some period in the spring. Material collected at Seattle the last of April, 1911, did not include this species, but in the king salmon smaller individuals had then produced from two to six broad rings of the new growth, and larger ones (from 18 inches up) contained usually no new growth. If this holds also in the dog salmon, the winter bands represent growth at ever-decreasing rate from July to May of the following year, the few wide summer rings representing sudden vigorous growth for but two or three months. This is of course insufficiently established.

Taking the great majority of specimens (in at least 90 per cent), the scales are perfectly typical and schematic, a glance with the aid of a simple lens being adequate to determine the age. This regularity and simplicity is also evident in the humpback salmon, and is in both species to be attributed to the fact that the young all have the same history, proceeding at once to sea, whereas in the other species, as has been shown, a dual habit is found.

Prof. McMurrich's contention that the dog salmon is a 4-year fish, with a nuclear area representing life in fresh water, has already been sufficiently answered. Plate VIII of his article has unfortunately the nuclear area so blurred in reproduction that its character can not be positively determined. If, however, this area was close-ringed "as in the sockeye and spring salmon, a central nucleus surrounded by a zone of fresh-water lines," the scale could hardly belong to the dog salmon. Such a description could not apply to plate IX, which represents obviously a 3-year-old scale, with the medial portion of the first winter band very narrowly divided but the two portions wholly fused at the sides. The significance of the so-called "spawning mark" we do not here discuss.

HUMPBACK SALMON (*Oncorhynchus gorbuscha*).

[Fig. 17, pl. x; fig. 29, pl. xvii.]

Available data concerning the habits of young humpbacks are derived almost wholly from Chamberlain's observations in Alaska. Like the dog salmon, the humpback young seek the sea as soon as they are able to swim. No yearlings have ever been reported from fresh water. In accordance with this habit, the nuclear area is consistently of the sea type, as in the dog salmon, being large in size and consisting for the most part of rings widely spaced. An inner nuclear core or region of narrowed rings is not infrequently present, and may here also simulate a close-ringed small nucleus of stream type. But the examination of a large series, taken in connection with the known history of the young, satisfies that such is never the correct interpretation.

No young humpbacks in their first year have come under our observation. Those listed by Chamberlain (op. cit., p. 55 to 57) were taken during the summer months and ranged from about 40 to 115 millimeters, the larger individuals being those of late summer. All were undoubtedly in their first year, and would yield interesting results on examination of their scales.

The possibility that the humpback salmon reaches maturity in less time than other species is considered by Chamberlain, who states: "The rapid growth of the young and the biennial occurrence of the species in Puget Sound may be noted in behalf of this belief." This suggestion that the species matures in its second year is wholly substantiated by the evidence of the scales (pl. x, fig. 17 and pl. xvii, fig. 29). A wide-ringed nuclear area of sea type, with its outer portion consisting of a definite winter band, is followed by the band of widely spaced rings representing the second summer's growth. Numerous individuals have been examined, representing all sizes readily secured in a spawning run, and all were uniformly in their second year. Statistics containing sizes of males and females have not been prepared.

Prof. McMurrich's inference from the humpback scales is correct, except perhaps that portion which recognizes in the central area of the scale a record of life in fresh water.

SUMMARY OF RESULTS.

The following conclusions can be drawn from data here presented:

1. The sockeye spawns normally either in its fourth or fifth year, the king salmon in its fourth, fifth, sixth, or seventh year, the females of both species being preponderantly 4-year fish.
2. The young of both sockeye and king salmon may migrate seaward shortly after hatching, or may reside in fresh water until their second spring. Those of the first type grow more rapidly than the second, but are subject to greater dangers and develop proportionately fewer adults.
3. Coho salmon spawn normally only in their third year. The young migrate either as fry or yearlings, but adults are developed almost exclusively from those which migrate as yearlings.

4. Dog salmon mature normally either in their third, fourth, or fifth years, the humpback always in their second year. The young of both species pass to sea as soon as they are free swimming.

5. The term "grilse," as used for Pacific salmon, signifies conspicuously undersized fish which sparingly accompany the spawning run. They are precociously developed in advance of the normal spawning period of the species. So far as known, the grilse of the king salmon, coho, and dog salmon are exclusively males, of the sockeye, almost exclusively males, except on the Columbia River, where both sexes are about equally represented. The larger grilse meet or overlap in size the smaller of those individuals which mature one year later at the normal period.

6. Grilse of the sockeye are in their third year, of the king salmon in their second or third year, of the coho and the dog salmon in their second year.

7. The great differences in size among individuals of a species observed in the spawning run are closely correlated with age, the younger fish averaging constantly smaller than those one year older, though the curves of the two may overlap.



FIG. 2.—Center of scale shown in figure 1. $\times 40$.



FIG. 1.—Sockeye scale, $\times 25$. From male, $17\frac{3}{4}$ inches long, grilse in third year. Bellingham, Wash., July 31, 1911.



FIG. 4.—Same scale as in figure 3, $\times 40$.



FIG. 3.—Sockeye scale, $\times 25$. From male, 25 inches long, in fourth year. Bellingham, Wash., July 31, 1911.



FIG. 5.—Sockeye scale, $\times 40$. From yearling, $3\frac{3}{4}$ inches long. Fraser River, April 26, 1903.



FIG. 6.—Sockeye scale, $\times 25$. From female, $19\frac{3}{4}$ inches long, in fourth year. Columbia River at The Dalles, Oreg., July 7, 1910.



FIG. 8.—King salmon scale, X 25. From male grilse, 21 inches long in third year. Everett, Wash., August 16, 1910.



FIG. 7.—King salmon scale, X 40. From immature male, 9 inches long, in second year. Everett, Wash., August 16, 1910.

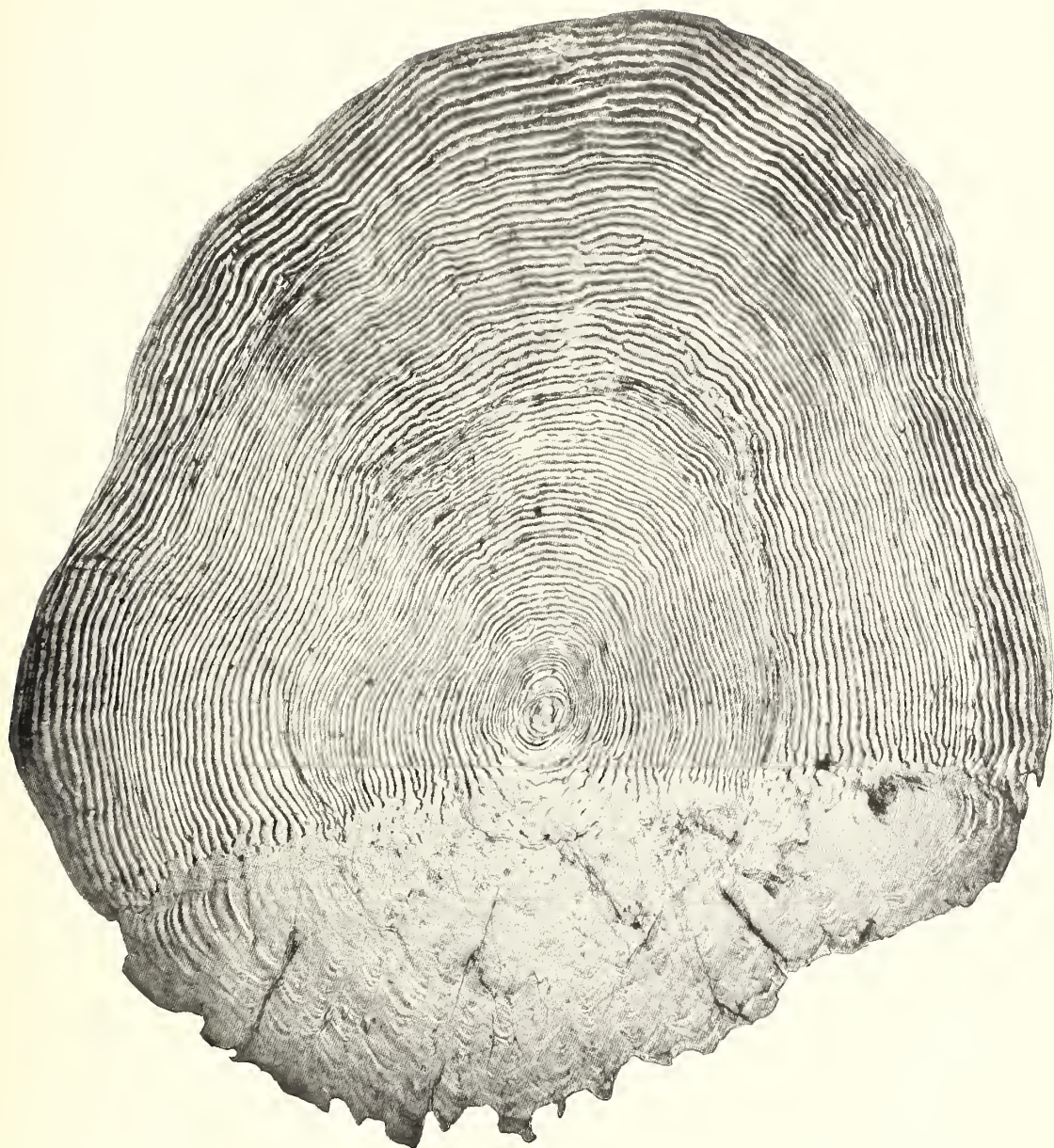


FIG. 9.—King salmon scale, $\times 25$. From mature female, 35 inches long, in fourth year. Bellingham, Wash., August 5, 1910.



FIG. 10.—King salmon scale, $\times 20$. From male, $48\frac{1}{2}$ inches long, in sixth year. Bellingham, Wash., August 3, 1910.



FIG. 13.—King salmon scale, $\times 40$. From immature male, 17 inches long, in second year. Anacortes, Wash., August 15, 1910.



FIG. 12.—King salmon scale, $\times 40$. From fingerling, $3\frac{1}{4}$ inches long, in first year. Friday Harbor, Wash., July, 1909.

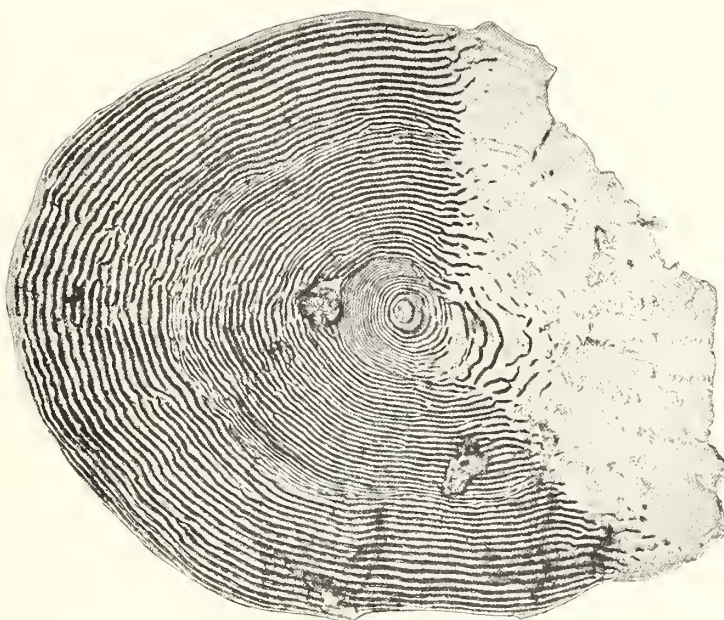


FIG. 11.—King salmon scale, $\times 25$. From mature male, grilse, $20\frac{1}{2}$ inches long, in third year. Everett, Wash., August 16, 1910.



FIG. 14.—Sockeye scale, $\times 25$. From male, 27 inches long, in fifth year. Bellingham, Wash., July 27, 1911.

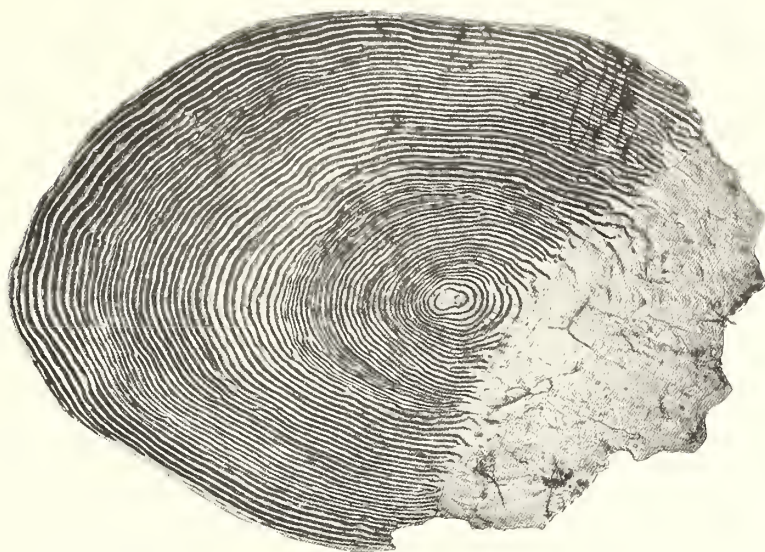


FIG. 15.—King salmon scale, $\times 25$. From mature male, 26 inches long, in third year. Columbia River at The Dalles, Oreg., July 9, 1910.



FIG. 16.—King salmon scale, $\times 40$. Center of scale shown in figure 25.



FIG. 18.—King salmon scale, $\times 25$. From mature female, 39 inches long, in fifth year. The Dalles, Oreg., July 10, 1910.



FIG. 17.—Humpback salmon scale, $\times 25$. From mature male, 25 inches long, in second year. Bellingham, Wash., August 2, 1910.



FIG. 19.—Coho scale, $\times 40$. From yearling, $4\frac{5}{8}$ inches long, taken at Swanton, Cal., April 23, 1910, during seaward migration.



FIG. 20.—Coho scale, $\times 40$. From immature female, $9\frac{3}{4}$ inches long, in second year. Everett, Wash., August 16, 1910.



FIG. 21.—Coho scale, $\times 25$. From mature male, $23\frac{1}{2}$ inches long, in third year. Monterey, Cal., July 3, 1911.

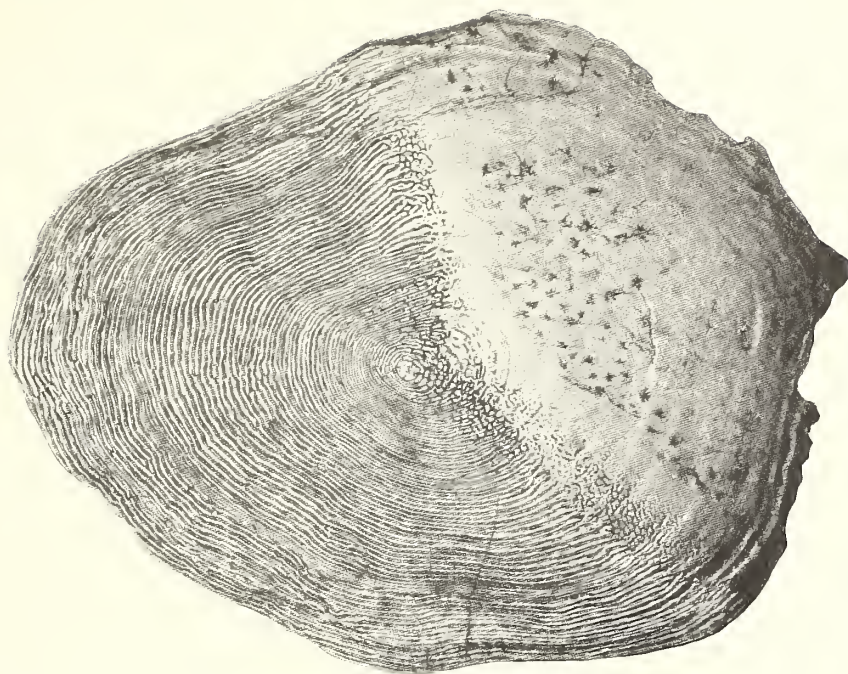


FIG. 22.—Sockeye scale, $\times 25$. From male, $26\frac{1}{2}$ inches long, in fourth year. Bellingham, Wash., July 31, 1911.



FIG. 23.—Dog salmon scale, $\times 40$. From specimen 6 inches long, in first year. Bellingham, Wash., August 2, 1909.



FIG. 24.—Dog salmon scale, $\times 25$. From mature male grisle, 21 inches long, in second year. Bellingham, Wash., August, 1910.



FIG. 26.—Dog salmon scale, X 25. From mature female, 25 inches long, in third year. Bellingham, Wash., August 3, 1910.



FIG. 25.—King salmon scale, X 25. From mature male, 26 inches long, apparently in third year. The Dalles, Oreg., July 9, 1909.



FIG. 27.—Dog salmon scale, $\times 25$. From mature male, $3\frac{1}{4}$ inches long, in fourth year.
Bellingham, Wash., August 2, 1910.



FIG. 28.—Dog salmon scale, $\times 20$. From male, $35\frac{1}{4}$ inches long, in fifth year. Bellingham, Wash., August 3, 1910.



FIG. 29.—Humpback salmon scale, $\times 40$. From mature female, 22 inches long, in second year.
Bellingham, Wash., August 3, 1910.

A NEW SPECIES OF TROUT FROM LAKE TAHOE



By John Otterbein Snyder
Stanford University

A NEW SPECIES OF TROUT FROM LAKE TAHOE.

By JOHN OTTERBEIN SNYDER,
Stanford University, California.

While engaged under the direction of the United States Bureau of Fisheries in an examination of the fauna of the various river basins that were at one time connected with the quaternary Lake Lahontan, a very remarkable species of trout was observed, which, although known to many sportsmen and fishermen, has entirely escaped the attention of ichthyologists. It is the purpose of this paper to record something of what is now known of its characteristics and present a preliminary description of the species.

Lake Lahontan, which in quaternary times was a large body of water very irregular in shape, extended over a considerable part of northern Nevada. By a shrinkage of the great lake, due to desiccation, a number of its tributary streams became detached and now remain as minor systems. Their waters ultimately disappear through evaporation or by sinking in the loose, dry sand of the deserts, which now cover the floor of the old lake, whose ancient terraces and gravel bars are plainly visible on every side. The largest and most important of these minor basins is that of the Truckee River, including Lake Tahoe and tributary streams, which form its source, and Pyramid and Winnemucca Lakes, into which the river flows, and where its waters are finally carried off by evaporation.

The rivers and lakes of the various basins which belong to the Lahontan system are well supplied with fishes, exceedingly abundant in number although representing but a few species. Of chief interest and value among these are the trout, which appear to have found the most advantageous conditions for growth and development in the Truckee River basin. A résumé of the information obtained from the more intelligent anglers shows that they here distinguish six varieties of native trout. Three forms are recognized in the lower portion of the basin, viz, the large redbfish, which in early spring ascends the Truckee River to spawn; the Tommy trout, which is smaller, darker colored, and more conspicuously spotted, and which ascends the river at a later date than the redbfish; and the greenback, a deep-water, silvery trout, which occurs in Pyramid Lake, presumably spawning there. Three varieties are distinguished also in the upper Truckee region: The Tahoe trout, dark in color, boldly and regularly spotted, ascending the tributaries to spawn; the silver trout, somewhat similar to the foregoing except that it is decidedly silvery in color, the spots are smaller and somewhat more elongate, and the body is deeper and heavier; and, finally, the royal silver trout, blue above, silvery on the sides, and almost entirely without spots.

In discussing the status of these forms anglers are found to differ considerably among themselves. Some distinguish two, three, or more of them, but none has been interviewed who recognizes all. Concerning the silver trout, it is difficult to find two men who entertain the same opinion. The writer first learned the name "royal silver trout" from Mr. Ralph Lowe, of San Jose, who caught a fine specimen and sent it to Stanford University. This was followed by another, which was presented to the university by Mr. F. K. Pomeroy, a graduate student in the department of medicine, and also by a third, caught by Mr. W. P. Lyon, of San Jose. Each of these was caught near Brockway, on the east side of Lake Tahoe. The collection was further enriched by another example, which had been sent to Dr. C. H. Gilbert by Mr. Charles A. Vogel-sang, the fish having been caught somewhere near Tahoe City. It is with these specimens representing the royal silver trout that the writer is at present most concerned.

Ichthyologists themselves have not been altogether unwavering in their discussions of Lake Tahoe trout. It seems, however, to be generally admitted that the Tahoe trout and silver trout belong to the same species, *Salmo henshawi* Gill and Jordan. A recent examination of an additional number of specimens seems to strengthen that conclusion. For the present, at least, the redbfish and the Tommy are considered as representatives of that species. The royal silver trout is, however, not to be confused with *S. henshawi*, for it evidently belongs to a distinct and well-characterized species, which may hereafter be known as *Salmo regalis*. This species does not appear to be closely related to either the cutthroat trout (*S. clarkii*, *S. henshawi*, and others) or the rainbow trout (*S. irideus*). The greenback trout of Pyramid Lake probably belongs to the same form.

Salmo regalis is distinguished above all else by its unusual color. A fresh specimen (the writer has not seen a living example) is of a beautiful deep steel blue on the dorsal surface, which in some lights seems to be tinted with olive, the blue extending downward on the sides to about the sixth row of scales above the lateral line, where it abruptly gives place to the most brilliant and highly burnished silver. The silver sheen grows dull on the ventral surface, the chin, throat, and abdomen being dead white. No dark spots are to be seen except on the dorsal and caudal fins, where they are very inconspicuous. No red or yellow color is to be found anywhere except on the cheek where it glows faintly through the silver. Structurally the species differs from the other native trout, *S. henshawi*, in having a shorter head, a shorter and more rounded snout, a much smaller maxillary, larger scales, narrower and more pointed fins, perfectly smooth basibranchials without teeth, fewer gillrakers. It differs also in other respects, which, together with those enumerated, will appear in the following description:

***Salmo regalis*, new species.**

Royal silver trout.

Head, 4.4 in length to base of caudal; depth, 4; depth caudal peduncle, 9.5; snout, 4.5 in head; length of maxillary, 2.1; vertical diameter of eye, 5.8; dorsal rays, 11; anal, 11; longitudinal series of scales above lateral line, 144; in series between lateral line and middle of back, 29; pores in lateral line, 120.

Body shaped as usual among trout, perhaps somewhat flatter than ordinary, the width contained $2\frac{3}{4}$ times in the depth near middle of body. Snout short and rounded; maxillary weak, narrow, and short, scarcely extending beyond a vertical through posterior edge of orbit. Opercles and branchiostegals rather thin and papery. Jaws weak; their teeth small and sharp; teeth in bands on vomer and palatines; 2 rows of 5 teeth each on the tongue; basibranchials smooth and without teeth. Branchiostegals, 11. Gillrakers on first arch, 7+12, slender and pointed. Lateral line almost straight from opercle to caudal. Scales very thin, not deeply embedded, moderate in size on the sides, extremely small on middle of back anterior to dorsal fin and on throat and abdomen. Fins all comparatively thin and frail, not like those of trout from mountain streams; pectorals and ventrals sharply pointed; dorsal and anal with slightly concave edges; caudal deeply cleft, the lobes pointed; adipose fin thin, narrow, and elongate.

Color in alcohol, dusky above, silvery on the sides, white beneath; dorsal and caudal fins dusky; anal somewhat dusky toward the border; pectorals and ventrals immaculate; no spots or bars on the head, body, or fins. On close examination the scales are observed to be silvery, those on the dorsal region closely speckled with black, those beneath with but little luster.

The type, which will be deposited in the United States National Museum, is a specimen measuring 323 millimeters in length, collected near Brockway, Lake Tahoe, Cal., August 23, 1912, by Mr. W. P. Lyon.

No external sex differences appear, a male and female being alike in all outward respects. Three of the specimens have 5 rows of small, elongate spots on the dorsal fin, some small spots on the caudal, and a few poorly defined spots on the dorsal part of the body. The latter did not become visible until the specimen had been in alcohol for some time. In the new species the maxillary averages 0.114 of the length to base of caudal; in *S. henshawi*, 0.145, as exhibited by 10 examples from Lake Tahoe, 0.147 in 10 from the Truckee River, and 0.14 in 10 from Pyramid Lake, the sexes being equally represented. The gillrakers differ as follows:

	S. regalis.			S. henshawi.			
Number on upper arch.....	7	8	9	9	10	11	.....
Number of specimens.....	1	2	1	10	18	2	.....
Number on lower arch.....	11	12	13	12	13	14	15
Number of specimens.....	1	1	2	2	9	17	2

The difference becomes more evident when the entire number on both limbs of the gill arch is taken into account, and this method of enumerating them is the better, as it is usually difficult to determine whether the one at the angle should be included with those above or below.

	S. regalis.			S. henshawi.			
Number of gillrakers.....	19	20	21	22	23	24	25
Number of specimens.....	1	1	2	4	11	13	2

Two examples of the new form have 42 and 57 cæca, respectively.

The measurements in the following table are recorded in hundredths of the length measured to the base of the caudal fin.

MEASUREMENTS OF SPECIMENS OF *SALMO REGALIS*.

Catalogue number.....	370	371	372	416
Length body.....mm.	305	225	270	250
Length head.....	.23	.235	.225	.235
Depth body.....	.22	.22	.245	.23
Depth caudal peduncle.....	.095	.09	.10	.095
Length caudal peduncle.....	.175	.18	.19	.18
Length snout.....	.05	.05	.05	.05
Length maxillary.....	.11	.12	.105	.12
Diameter eye.....	.04	.045	.04	.04
Interorbital width.....	.07	.07	.075	.08
Depth head.....	.16	.16	.16	.155
Snout to occiput.....	.16	.15	.145	.146
Snout to dorsal.....	.49	.48	.48	.51
Snout to ventral.....	.56	.54	.52	.54
Length base of dorsal.....	.12	.12	.14	.13
Length base of anal.....	.11	.11	.10	.198
Height dorsal.....	.12	.12	.14	.14
Height anal.....	.13	.125	.13	.12
Length pectoral.....	.15	.15	.16	.15
Length ventral.....	.12	.12	.14	.125
Length caudal.....	.20	.20	.22	.22
Dorsal rays.....	10	10	11	10
Anal rays.....	11	11	11	11
Pectoral rays.....	14	14	.....	14
Scales lateral series.....	152	153	144	150
Scales above lateral line.....	30	31	29	29
Branchiostegals.....	12	13	11	12
Sex.....	♀	.....	♂	.....

Specimens of this species are not often taken, and they seem to be growing less common from year to year.

DESCRIPTION OF A NEW DARTER FROM MARYLAND



By Lewis Radcliffe and William W. Welsh

DESCRIPTION OF A NEW DARTER FROM MARYLAND.



By LEWIS RADCLIFFE and WILLIAM W. WELSH.



There are about 15 known species of darters belonging to the genus *Hadropterus*. Of these only two (*H. pellatus* and *roanoka*) have been reported east of the Alleghenies and north of the Carolinas. In North Carolina, *H. evides*, which is common west of the Alleghenies, here occurs on the Atlantic slope. The range of *H. nigrofasciatus* extends from South Carolina to Louisiana. The remaining species are found in the Mississippi Basin, Great Lakes, and southwestern streams. The members of this genus are active, graceful, and usually of brilliant coloration.

The examples of the new species herein described were seined in Swan Creek, near Havre de Grace, Md., in water 6 inches deep, on a long, stony riffle, where the bottom was comparatively free from boulders and the current so swift that one would not have expected to find fishes of any kind.

Hadropterus sellaris, new species.

Dorsal XI-11,i; anal II,8,i; pectoral 14; scales 5+6-46 (+3).

Head 3.66, considerably broader than deep, parietal region rather depressed; body slender, fusiform, not markedly compressed, greatest depth 5.09; caudal peduncle slender, as long as head, its depth 2.75 in its length, eye 3.67, subcircular, dorso-lateral; snout 3.14; interorbital very narrow, 2.4 in diameter of eye; mouth rather wide, terminal, lower jaw included; maxillary 2.82, reaching nearly to vertical from anterior margin of pupil, premaxillaries not protractile, the broad frenum connecting them with the skin of the forehead without groove; teeth small, vomerine and palatine teeth present.

Spinous dorsal low, fourth spine longest, 2.20 in head; second dorsal somewhat higher, second ray longest, 1.80; distal edge of caudal emarginate, anal low, sixth ray longest, 1.83; ventrals 1.21, rather widely separated at base, tips of spine and anterior rays expanded, adipose; pectorals broad, slightly longer than head, reaching to behind the vent, tips of lower rays expanded, adipose.

Opercle and cheeks to below middle of eye scaled, rest of head naked, back in front of dorsal, breast, and belly naked; scales large, regular in arrangement, about as deep as long, the free portion with a submarginal row of well-developed spinules; lateral line nearly straight, not arched anteriorly.

Color in alcohol: Ground color light smoke-gray, becoming white on ventral surface; back crossed by four black saddles with light margins, broadest dorsally, narrower than interspaces, the first extending across back in front of spinous dorsal downward to base of pectoral, the second, lying between base of next to last dorsal spine and origin of second dorsal, extends downward and forward below lateral line; the third, from sixth to last dorsal ray, extends downward and forward to within two scales of base of anal; the fourth, crossing back in front of base of caudal, extends downward and slightly forward to

ventral surface of caudal peduncle. Lying below the lateral line, and alternating with the black saddles are four black quadrate blotches, the last being on base of caudal. Several scales on either side of base of spinous dorsal between first and second saddle black. Dorsal spines with a few dusky or black markings; the soft dorsal crossed by three rows of blackish spots, these confined to the rays; caudal with dusky mottlings; anal and ventrals white; pectoral crossed by five more or less concentric rows of blackish spots; axil white. Opercle and top of head dusky, a black spot behind eye, a black bar in front of eye, a second below eye, and a third from upper margin of pupil to interorbital, apparently a continuation of the second.

In life the reddish-brown ground color and jet-black saddle markings present a very striking appearance.

Type: Catalogue no. 74346, United States National Museum, 4.9 cm. in length, from Swan Creek, Md., May 2, 1912.

The cotype, 4.9 cm. long, agrees with the type in the form of fins, scaling, and coloration; and has dorsal x-11,i; anal 11,8,i, pectoral, 14, scales, 5+9-50 (+3), head, 3.66; depth, 5.17; length of caudal peduncle equal to maxillary, 2.82, interorbital, 2.38 in eye.

The differences between *H. sellaris* and *H. peltatus*, the only other species whose range coincides, may be seen from the following comparative table, based on the type and cotype of the new species and on 6 specimens of *H. peltatus* from Mattaponi River, Va. (No. 69716, U. S. National Museum).

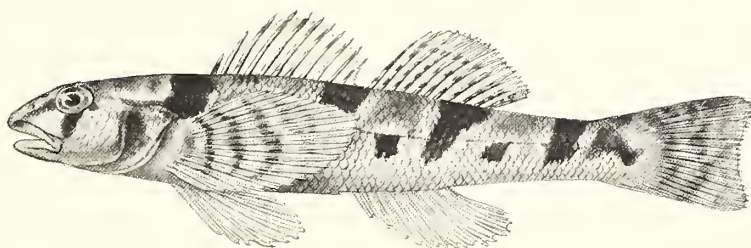
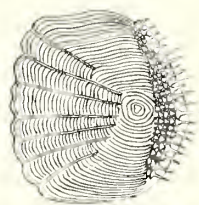
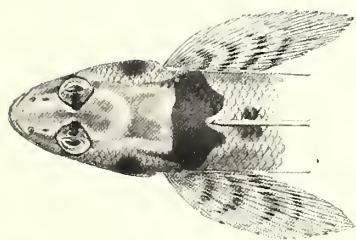
COMPARISON OF MEASUREMENTS OF *HADROPTERUS SELLARIS* AND *H. PELTATUS*.

Items.	Hadropterus peltatus.						H. sellaris.	
Total length.....	6.55 cm....	5.5 cm....	5.0 cm....	5.0 cm....	4.9 cm....	4.7 cm....	4.9 cm....	4.9 cm.
Dorsal formula.....	XIV-12,i...	XIII-13,i...	XIII-12,i...	XV-11,i...	XIII-12,i...	XIII-11,i...	XI-11,i...	X-11,i.
Anal formula.....	II,9.....	II,9.....	II,8,i...	II,8,i...	II,8,i...	II,8,i...	II,8,i...	II,8,i.
Scales.....	6+9-56....	5+8-57....	6+10-52...	6+10-53...	5+9-55....	6+8-57....	4+6-46....	5+7 right ^a -50
Eye in head.....	3.47.....	3.47.....	3.12.....	3.37.....	3.31.....	3.43.....	3.07.....	3.55.
Snout in head.....	3.47.....	3.90.....	3.86.....	3.93.....	3.87.....	4.48.....	3.14.....	3.14.
Maxillary in head.....	3.12.....	3.20.....	3.05.....	3.11.....	3.05.....	3.22.....	2.82.....	2.82.
Interorbital in head.....	6.24.....	6.25.....	5.50.....	5.90.....	5.52.....	5.15.....	8.80.....	8.40.
Interorbital in eye.....	1.80.....	1.80.....	1.62.....	1.75.....	1.66.....	1.50.....	2.40.....	2.38.
Interorbital in snout.....	1.80.....	1.60.....	1.43.....	1.50.....	1.43.....	1.15.....	2.80.....	2.69.
Pectoral in head.....	1.27.....	1.10.....	1.16.....	1.12.....	1.16.....	1.03.....	.92.....	.92.

^a Left side, 9.

BULL. U. S. B. F., 1912.

PLATE XVIII.



Hadropterus sellaris, new species.

THE SENSE OF SMELL IN FISHES



By G. H. Parker and R. E. Sheldon

THE SENSE OF SMELL IN FISHES.



By G. H. PARKER and R. E. SHELDON.



INTRODUCTION.

That fishes scent their food in the water much as many land animals do in the air is a belief that is held by many fishermen. This opinion has led to the practice of chumming or baiting up; i. e., of spreading bait in a region preparatory to fishing it, a practice that, in the case of sharks, mackerel, and bluefish, seems to be justified by the results. Such practice is based on the assumption that fishes have a sense of smell, but this opinion has been unsupported by physiological evidence, for up to the present time investigators of the subject have not been able to demonstrate any form of stimulation or reaction characteristic of the olfactory apparatus in water-inhabiting vertebrates. The observations of Aronsohn (1884, p. 164) that a goldfish which ordinarily will eat ant pupæ with avidity will not take these pupæ after they have been smeared with a little oil of cloves, are not conclusive evidence that the fish scents the oil, for it is entirely possible that this oil merely irritates the skin of the fish's snout and does not stimulate the olfactory apparatus at all. Nor is the discovery made by Steiner (1888, p. 47), that the spontaneous appropriation of food by the shark *Scyllium* ceases on the removal of the cerebral lobes or simply on cutting the connections between these lobes and the olfactory bulbs, satisfactory evidence that the olfactory apparatus in these fishes is an organ of smell rather than a receptor for taste or some closely allied sense.

Nagel (1894, p. 184) noted that the rostral portion of the head of *Barbus* was as sensitive to sapid substances after the olfactory tracts had been cut as before that operation, and Sheldon (1909, p. 291), studying the dogfish, demonstrated that the decided sensitiveness of the nostrils of this fish to weak solutions of oil of cloves, pennyroyal, thyme, etc., was not influenced by severing the olfactory crura, but disappeared on cutting the combined maxillary and mandibular branches of the trigeminal nerve. Evidently the nostrils of fishes, like those of the higher vertebrates, are innervated by fibers from the trigeminal nerve, and it is this nervous mechanism rather than the olfactory apparatus that is stimulated by the substances that have ordinarily been applied by experimenters. In fact, so far as the olfactory apparatus of the fishes and amphibians is concerned, we must agree with Nagel (1894, p. 61) that no one thus far has discovered anything positive concerning its function. It is, therefore, a matter of interest to record what seem to be unquestionable reactions dependent upon the olfactory apparatus of three of our common fishes: The fresh-water catfish (*Ameiurus nebulosus*),

the smooth dogfish (*Mustelus canis*), and the killifish (*Fundulus heteroclitus*). The work on *Ameiurus* and *Fundulus* was done by G. H. Parker, that on *Mustelus* by R. E. Sheldon.

EXPERIMENTS WITH AMEIURUS.

Ameiurus nebulosus is a bottom-feeding fish possessing fair powers of sight and unusual gustatory organs located not only in the mouth and on the general outer surface of the body, but especially on the eight barblets about the mouth (Herrick, 1903). It is a hardy fish, living well in confinement and undergoing operations with success. It possesses near its anterior end a pair of nasal chambers, each of which is provided with two apertures, one anterior, the other posterior. The anterior aperture is nearly circular in outline and is located on a slight conical elevation somewhat anterior to the root of the dorsal barblet. The posterior aperture is slit-like in form and lies immediately posterior to the same barblet. The anterior aperture is apparently always open; the posterior one seems capable of slight closure, but is usually freely open.

By keeping catfishes a few days without food they can be made most eager for it, and if into an assemblage of such individuals a few fragments of fresh earthworms are dropped, the excitement that ensues will last some time after the final piece of worm has been swallowed. During this period the fishes swim about actively in the lower part of the aquarium, now in this direction, now in that, and frequently sweep the bottom with their barblets. As can be noticed when feeding actually occurs, the fishes seldom seize a fragment of worm until their barblets have come in contact with it. Yet before they have thus touched any food they show a marked degree of excitement and it is this initial nervous state that would lead an observer to suspect that they scented their food. This phase of their activity was, therefore, taken as the one to be tested in connection with their olfactory organs.

The nasal chambers of the catfish contain ciliated epithelium, the action of which is to draw water in at the anterior olfactory opening and discharge it at the posterior one. As can be demonstrated with carmine suspended in water, the passage through the chamber is accomplished in 8 to 10 seconds.

As a preliminary step in testing the catfishes, five normal fishes were placed in a large aquarium over night that they might become accustomed to their surroundings. In this aquarium were then hung two wads of cheesecloth, in one of which was concealed some minced earthworm. The fishes, which were swimming about near these wads, were then watched for an hour and their reactions in reference to the wads were recorded. The wad without worms was passed by the fishes many times and did not excite any noticeable reaction. The wad containing the worms was seized and tugged at eleven times in the course of the hour, notwithstanding the fact that from time to time this and the other wad were interchanged in position. Not only did the fishes thus openly seize this wad, but when in its neighborhood they would often turn sharply as though seeking something without success, a form of reaction seldom observed near the wad which contained no worms. Two other sets, of five normal fishes each, were tested in this manner and with similar results. It was perfectly clear to anyone watching

these reactions that the fishes sensed the difference between the wad of cloth with worms and that without worms.

To ascertain what receptive organs were concerned in the reactions just described, two sets of 5 fishes each were taken from among the 15 normal fishes already tested, and each set was prepared differently by subjecting its members to a special operation. One set was etherized, and, through a small incision between the eyes, their olfactory tracts were cut, thus rendering their olfactory apparatus functionless. From fishes of the other set all the barblets were removed, whereby their external gustatory organs were partly, though not wholly, eliminated. After these operations both sets of fishes were liberated in the large aquarium, where they remained for over two days. At the expiration of this time, they were carefully inspected and tested. They swam about in an essentially normal way and members of both sets snapped bits of worm from the end of a hooked wire much as a normal fish does. Presumably they were in a satisfactory condition for experimentation.

The tests were begun by introducing into the large aquarium containing the 10 fishes a wad of cheesecloth within which were hidden some minced earthworms and recording the kind of fish that visited it and the nature of their reactions. During the first hour the wad was seized 34 times by fishes without barblets but with normal olfactory organs and, though often passed by fishes with cut olfactory tracts, it was "nosed" only once by one of these. A wad of cheesecloth without worms was next substituted for that with worms and the reactions of the fishes were recorded for a second hour. Though members of both sets frequently swam by this wad, none at any time during the hour seized it or even nosed it. These tests were repeated on the same fishes for two succeeding days and with essentially similar results. On the second day the wad with worms was seized 16 times during the test hour by fishes with normal olfactory organs and on the third day 54 times. On both these days the fishes with their olfactory tracts cut made no attempts on the wad with worms nor did any fish at any time nose the wormless wad. The movements of the two sets of fishes when in the neighborhood of the wad containing minced worms were characteristically different. The fishes with their olfactory tracts cut swam by the wads without noticeable change; those without barblets, but with their olfactory apparatus intact almost always made several sharp turns when near the wad as though seeking something, and then either moved slowly away or swam more or less directly to the wad and began to nose and nibble it. These reactions were so clear and so characteristic that when taken in connection with the conditions of the fishes, they lead inevitably to the conclusion that the olfactory apparatus of the catfish is serviceable in sensing food at a distance much beyond that at which the organs of taste are capable of acting; in other words, catfishes truly scent their food.

EXPERIMENTS WITH MUSTELUS.

The experiments here recorded were performed on the smooth dogfish, *Mustelus canis* (Mitchell). This was selected owing to its great abundance in Buzzard's Bay near Woods Hole, and also because previous experimentation (Sheldon, 1909) rendered many of its habits and reactions familiar.

Bateson, Nagel, and others believed that selachians recognize their food through the sense of smell; their evidence is, however, valueless in this connection owing to the fact that irritating substances were used as tests, or else no distinction between smell and other chemical senses was made. Mr. Vinal Edwards, collector for the Woods Hole Laboratory of the Bureau of Fisheries, states that it is the custom in fishing for dogfish to throw out in the tide lines baited with menhaden or alewives. For a time no dogfish will be seen, then they will appear in numbers, swimming around the bait in gradually diminishing circles until finally it is seized. Field (1907) finds that the dogfish carefully search the bottom for crabs. Finding one they turn on their sides to seize it, then dart off quickly, shaking the crab as a terrier would a rat. After swallowing the food, Field states that the dogfish keeps up its active swimming, often returning to the place where the crab was found.

Some experiments on the relation of the olfactory apparatus of the dogfish to its feeding habits were undertaken in the summer of 1908, but failed owing to the fact that the fishes refused to eat in captivity. These experiments and those of Field show that dogfish will not eat if kept in large tanks or even in the large cod cars of the station, even though they are kept in captivity to the point of emaciation. In order, therefore, to give them a habitat comparable to the normal, a portion of the large observation pool of the station was fenced off with meshed wire. This gave a pool 24 feet long, 8 feet wide at one end, and 10 feet wide at the other, with normal sea bottom, an irregular stone wall on three sides, and a depth of water of from 2 to 8 feet, depending on the portion of the pool considered and the height of the tide. Tufts of eelgrass, together with many other varieties of sessile marine life, grew on the bottom and sides. The pool, therefore, fulfilled to a reasonable degree the conditions of normal life, so far as the dogfish are concerned.

The individuals used were those caught in the traps from day to day and placed in the pool for a period of 10 days in order to bring about a state of hunger.

Spider or blue crabs were first offered the dogfish, but were always refused. The rock crab, *Cancer irroratus*, was next tried, with success, and used for all the experimental work. All experiments were conducted at low tide, when it was easy to observe the actions of the individual fishes. At first living crabs were used. These were found by the dogfish in from 10 to 15 minutes. Next, crabs were killed and a hole broken in the carapace, exposing the flesh. Such were found in from 2 to 5 minutes. These results suggest at the start that the food is recognized through the diffusion of animal juices into the water. Crabs killed, with the flesh thus exposed, were used for all further work.

In a total of about 40 experiments the method of feeding was the same in all cases. The dogfish spent most of the time swimming lazily around the pool, usually close to the sides. Now and then the direction was reversed, but at no time was there observed any search over the bottom or the rocks forming the sides of the pool. When a crab was placed in the pool, a few minutes was required, as noted, before any evidence of stimulation was to be seen. Then one of the dogfish which happened to be swimming within 3 or 4 feet of the crab seemed suddenly startled. It turned very quickly, and

swimming with quick, nervous motions, instead of the calm, lazy movement of the unstimulated fish, began a systematic search over the bottom, investigating particularly grassy or uneven spots. The head was moved rapidly from side to side as the fish swam slowly, coursing, in gradually diminishing circles, 2 or 3 inches from the bottom. When within 2 or 3 inches of the crab the dogfish seized it suddenly, making off in a swift rush. As remarked by Field, the crab is shaken violently from side to side for a moment, as the shell is crunched and broken by the powerful jaws of the fish, after which it is quickly swallowed. Occasionally, however, the crab is dropped during the process; when this occurs, a search similar to the first follows until it is found again.

At no time did the dogfish appear to make any use of the sense of sight in feeding. A crab hidden in eelgrass is found as quickly as one lying on the open bottom; moreover, one is found with equal promptness whether lying on its venter, exposing the dark carapace, or on its dorsum, with the light-colored venter showing conspicuously. A dogfish, dropping a crab, is apparently unable to find it again excepting by means of the same sense which enabled recognition of food in the first place. It was observed, however, that a dogfish with food is usually followed by others in the vicinity, which endeavor to secure possession of it. Moreover, the fish will frequent for some time thereafter the region of the pool in which food was found. This is probably due to olfactory stimuli, although sight may be brought into play to a slight extent. It was often noted that a dogfish would circle around the spot where a crab had lain, often biting into the bottom at the exact spot; probably some body juices had escaped into the ground. Now and then a crab was placed on the bottom near the screen separating the experimental from the larger pool. If no fish capable of finding food were present in the former, it would often happen in a few minutes that 8 or 10 dogfish from the large pool would be swimming rapidly back and forth along the screen, endeavoring to find their way through.

Some experiments were tried with a hook and line baited with the flesh of a rock crab tied in cheesecloth. The dogfish here follow the same procedure as when the crab lies on the bottom. On noting the proximity of food the fish begin to swim, as before, in circles, but for a time persistently search the bottom beneath the baited hook. At length they gradually rise, turning somewhat sidewise, as stated by Field, to seize the bait. When the food is lying on the bottom this sidewise turning was never observed.

Observation of the feeding habits of the dogfish would indicate, then, that it recognizes its food through some chemical sense. To test this the following experiments were performed:

Some fresh eelgrass was secured and two packets, closely resembling each other, were made, one containing a small stone, while the other inclosed a crab. Both were so tied that when placed in the water a foot apart a portion of the grass rose toward the surface, giving an appearance similar to the grass of the pool. In three sets of experiments the presence of food was detected in an average time of three minutes, the packet found by the usual procedure, torn apart, and the crab eaten. At no time did the packet containing the stone receive the slightest attention.

Next two packets of white cheesecloth of a similar size and appearance were made up. One of these contained a stone, the other a crab. This experiment was repeated four times on different days. The packet containing the crab was found in each case in from 3 to 5 minutes, while the one with the stone was never molested. The two packets were placed from 10 inches to 3 feet apart. Once or twice a dogfish which had eaten a crab would return and, circling about the spot where the crab had been found, would approach the packet containing the stone in an inquiring sort of way but at no time touched it. The packet containing the crab was always shaken and bitten until the food could be removed and eaten.

A crab was killed and a piece of white cheesecloth saturated in its juices. This was then attached to a small stone. In two experiments the presence of a food substance was noted in two minutes. The stimulus was located by the usual circling method and the stone, with its saturated cloth, seized again and again and shaken violently. After a half hour the fish took no further notice of it, probably because of a complete diffusion of the juices in the water.

In all the above experiments a number of different sets of dogfish were used. There were usually from 6 to 8 fish in the pool at a time. Normally only one or two experiments a day were performed, in order that there be no interference between them.

These observations show beyond doubt that the dogfish obtains its food through the use of a chemical sense. Experiments were now undertaken to find out what part the olfactory apparatus plays in these reactions.

Four dogfish which had eaten readily when in the normal condition were removed from the pool and their nostrils stuffed with cotton wool; in two of the cases the cotton was covered with vaseline. When returned to the pool such fish rush about violently for a few minutes, as do all dogfish which have been out of water. They soon, however, quiet down and swim about the pool as do the normal fish. Twenty-four hours later three crabs were placed, an hour apart, in the pool, which now contained, in addition, four normal fish. All were found, in the usual manner and length of time, by the fish without cotton in the nostrils. At no time did any of the individuals with the nostrils filled show the slightest interest in the crabs, although such often swam within a few inches of the food. Moreover, these fish made no attempt to follow those which had secured one of the crabs, although the food was occasionally dropped. It was often observed that two dogfish, one normal and the other with the nostrils filled, would be swimming along the wall side by side when they approached the vicinity of the crab; the normal fish would then make the usual sudden turn to search for food, while the individual with the cotton continued on its way with no change in the lazy swimming movement. As it was noted that vaseline or a close packing of the nostrils with cotton caused suppuration in time, this experiment was repeated three times with the cotton loosely packed. Results similar to the above were secured in all cases. Two tests were made, also, in which there were no normal fish in the pool. In these cases the crabs were left untouched for 24 hours, although the dogfish on the opposite side of the screen became much excited.

Three of the dogfish, all of which had eaten readily before the use of the cotton, but which had refused to do so thereafter, although tested for three successive days, were removed from the pool and the cotton withdrawn from the nostrils. These were returned to the pool, which now contained no normal fishes. The following day one of these ate readily in the usual manner, although there seemed to be slightly more difficulty than usual in finding the crabs, both in the first place and after one had been dropped. A day or two later all three ate as usual. This experiment was repeated twice with the same results.

These experiments indicate that the dogfish normally recognize the proximity and location of food through the use of the olfactory apparatus. It may be argued, of course, that the mere presence of the cotton in the nostrils renders the fish so uncomfortable that it refuses to eat, even though it act otherwise in a perfectly normal manner. To obviate this objection four dogfish were removed and one nostril only stuffed with cotton. These four only were now placed in the pool. One of these, within an hour thereafter, caught a crab after the usual preliminary procedure, but lost it and then seemed to take no further interest in the matter. The following day all four ate as usual. It was noticed in this experiment, also, that the dogfish had rather more difficulty than normally in finding the food, but that this wore off in a couple of days. These four fish were removed after four days, and seven others, fixed in the same way, were substituted. The results were the same. These tests show that the presence of the cotton is not sufficiently irritating to interfere seriously with the normal feeding habits of the dogfish. As remarked earlier, individuals with the nostrils plugged act, except in so far as the feeding habits are concerned, just as do the normal fishes. As both kinds swim about the pool, such could not be identified by an uninformed observer.

The nasal apparatus of the dogfish consists of a pair of large capsules, partially divided into two parts by means of a superficial and inclosed flap of skin rostrally and a fleshy ridge caudally. There are thus two incompletely separated apertures, a rostralateral and a caudomedian, the latter closer to the mouth. (See Sheldon, 1909, fig. 3.) The capsules contain a double row of lamellæ, extending laterally from a median ridge much as do the barbs from the rachis of a feather. This ridge extends from the more lateral to the more medial opening. The lamellæ are innervated by an enormous number of short olfactory nerve fibers which terminate in the large olfactory bulbs, closely apposed to the capsules. The *nervus terminalis* of Locy also sends a few fibers into the lamellæ, while the capsules, in general, are innervated for tactile and general chemical sensation by the *nervus maxillaris trigemini*.

During the ordinary movements of respiration, as water is taken into the mouth, a current is, by suction, drawn through the nostrils, entering the more rostral and leaving at the more caudal aperture, to be drawn farther, to some extent, into the mouth. This may be easily demonstrated by fastening a dogfish on its dorsum and expelling, from a pipette, a colored solution rostrally of the nostrils. The current, then, follows the median ridge, a part being diverted laterad between the lamellæ. The shape and

position of the fleshy ridge and flaps of skin are such, also, that a fish in forward locomotion forces water through the nostrils. A dogfish is, therefore, whether in motion or at rest, constantly receiving through its nasal capsules a current of water.

EXPERIMENTS WITH *FUNDULUS*.

The olfactory apparatus of the killifish, like that of the catfish, consists of a pair of sacs each provided with two apertures, one anterior, the other posterior. The anterior olfactory aperture is just above the upper lip and dorsal to the angle of the mouth. It is a small roundish opening not unlike one of the pores of the lateral line system and is on the summit of a low elevation. The posterior aperture is an elongated slit somewhat dorsal to the anterior limit of the eyeball. The mouth of the posterior aperture is partly occupied by a valve-like fold of skin.

If the quiescent head from a freshly killed *Fundulus* is examined in water, no motion is observable about the olfactory apertures. Suspended carmine is not carried into them nor discharged from them; in other words, there is no evidence of a ciliary current passing through the olfactory sacs such as is so easily demonstrated in the catfish. If a head in which the respiratory movements of the gills are still in progress is examined, well-marked currents can be demonstrated in the olfactory organs. Suspended carmine is taken in at the anterior aperture and discharged from the posterior one. With each respiratory movement, the valve in the posterior aperture opens, a small amount of water is discharged, and it then closes. This passage of water through the olfactory apparatus is apparently due to the changes of pressure produced by the rhythmic activity of the muscles of the gills probably acting in conjunction with valves within the olfactory sacs. The movement of the valve at the posterior aperture follows exactly that of the respiratory apparatus and its automatic character is obvious from the fact that if an anterior aperture in an active fish is closed by having its walls stitched together so that no current of water can enter the sac at that point, the posterior valve of the same side ceases to pulse, though that of the other side continues in normal activity. If, now, the closed aperture is reopened by removing the stitches, the valve previously quiescent begins again to pulse. Thus, though *Fundulus* has no continuous current through its olfactory sacs, such as the catfish has, it does have a well-developed intermittent current that is not inappropriately designated as respiratory, though this current is in no direct way concerned with the respiratory function. Apparently as long as the gill muscles of *Fundulus* carry out the respiratory movements, currents of water run through the olfactory sacs.

As a preliminary test to ascertain whether *Fundulus* could discover hidden food or not, packets of cotton cloth containing dogfish meat wrapped so as not to be visible and packets made of nothing but cotton cloth were hung in an aquarium in which there were a number of hungry *Fundulus*. After the packet had been thoroughly soaked in the sea water, the reactions of the fishes to them were watched. The packets without meat were occasionally approached and seized, but soon dropped. Those that contained meat were sooner or later surrounded by most of the killifish, which carried

on a vigorous competition as to which would have possession of the packet. Frequently the first comer would not only seize the packet and tussle with it, but would often attempt to drive off other fish that had approached the region, attracted apparently by the movements of the first fish. These preliminary tests showed quite conclusively that the normal killifish responds very quickly and in a characteristic way to hidden food.

It was also quite evident from these tests that the killifish, in strong contrast with the catfish and dogfish, uses its eyes as well as its chemical senses in seeking and retaining its food. If a small piece of dogfish flesh is dropped into an aquarium in which there are hungry killifish, one is almost sure to pounce upon the fragment and swallow it quickly. This action is so sudden and begins when the fish is at such a distance from the bit of flesh that it is evidently controlled through the eye. That it is not entirely so, however, is seen from the fact that if a small ball of filter paper is thrown into the water, this too is pounced upon and taken into the mouth but soon discharged. Thus the sight of an object must be followed by an appropriate stimulus of smell or taste, if the object is to be swallowed.

It is the eye, apparently, that leads killifish to swim to a packet of plain cloth and seize it, even though it contains no food. The fact that the fishes do not remain about such a packet long, however, shows how clearly they distinguish it from a packet in which meat is hidden and around which they will gather and tussle for long periods of time. The use of the eye in the preliminary steps of search for food is shown in the amusing habit that these fish have of chasing drops of water down the glass face of an aquarium as if they were bits of food. The eye, then, in *Fundulus* is serviceable in the initial stages of procuring food, but whether the material is to be persistently nibbled and finally swallowed depends, as the preceding tests show, on senses other than sight.

The part played by the olfactory organs in reactions to hidden food can be determined by first eliminating these organs and then testing the fishes. The olfactory apparatus can be rendered inoperative by cutting the olfactory tracts in a position where they are easily accessible as, for instance, between the eyes. In this situation a small incision can be made through the thin bony roof of the skull and the two tracts can be cut by a single movement of a narrow blade. Twenty-four hours after such an operation the fish were fully active, took food, and in all obvious ways seemed normal. When two packets of cloth, one with dogfish meat hidden in it and the other without this food, were suspended in the aquarium in which the operated fishes were, these animals nibbled temporarily both packets in a way that made it impossible for an uninformed observer to distinguish one packet from the other. When these two packets were transferred to an aquarium of normal fish, the one containing the food was soon surrounded by a vigorously contesting assembly of fishes, whereas the packet without food was only occasionally nibbled. The evidence from these experiments favors the view that the olfactory organs are necessary to *Fundulus* in sensing hidden food. The severity of the operation, however, renders this evidence not wholly conclusive.

In order to carry out tests in which the objection could not be raised that the results might be due to the shock of cutting nerves rather than to the loss of a sense organ, the following procedure was employed: By taking two stitches of very fine silk thread, one on either side of the external olfactory aperture, it was comparatively easy to close this aperture, and thus to prevent any passage of water through the olfactory sacs. Killifish which previous to the operation gave markedly different and characteristic reactions to the two classes of packets already described reacted to both kinds of packets after their anterior olfactory apertures were closed, as they had previously done to the packets that contained no food. That this reaction was not to be directly attributed to the operation of stitching up the apertures was demonstrated in two ways. If, after the stitches were taken, the thread was not drawn up and tied so as to close the aperture, but the ends were allowed to remain free, the fish would react as normal fishes do to the two classes of cloth packets, thus showing that the mechanical injury due to the stitches themselves did not influence the fish in any essential way. Further, if fishes whose anterior olfactory apertures had been closed by stitching and tying, and whose discrimination for the two classes of packets had thereby been lost, had their olfactory apertures reopened by cutting and removing the thread, they very soon regained their capacity to distinguish packets with food from those without food; in other words, they soon returned to the condition of normal fishes. For these reasons it is believed that stitching up of the anterior olfactory aperture is in itself not a disturbing operation for the fish and that the loss of the ability to recognize the presence of hidden food is in reality due to the loss of the olfactory function.

CONCLUSIONS.

Whether such olfactory reactions as those that have just been described are really due to smell or not is regarded by some authors as an open question. Nagel (1894, p. 56), who has discussed this matter at some length, concluded on rather theoretic grounds that fishes could not possibly possess a sense of smell and that their so-called olfactory organs act more as organs of taste than of smell. Possibly the whole matter is merely one of definition. With human beings smell differs from taste chiefly in the concentration of the stimulating solution and not, as was formerly supposed, on the state of the stimulating material, for, though we usually say that we smell gaseous or vaporous materials and taste liquids and solids, all these substances are in reality dissolved on the moist surfaces of whichever sense organ they stimulate. The most striking difference between smell and taste with us is that we smell extremely dilute solutions and taste only very much more concentrated ones. As a result we recognize the presence of many distant bodies by smell and not by taste, for the very minute amount of material that reaches us from the distant body will form a solution on our moist surfaces that will be stimulating for our organs of smell, but not for our organs of taste. Hence our olfactory organs as compared with our organs of taste are what Sherrington (1906) has called distance receptors, a designation justly emphasized by Herrick (1908). Although this distinction between taste and smell is one of degree rather than of kind, it seems to us

reasonably sound, and it certainly holds in the case of fishes much as it does with human beings, for these animals respond through their olfactory organs to solutions too dilute to affect their gustatory organs, and the nature of the response to olfactory stimulation (seeking food, etc.) is such that the olfactory organs in these fishes can be called appropriately distance receptors. We, therefore, believe that the fishes, although water-inhabiting animals, possess olfactory organs that are as much organs of smell as are the olfactory organs of the air-breathing vertebrates.

SUMMARY.

1. A current of water passes through the nasal chambers of many fishes in a direction from anterior to posterior. It may be produced by ciliary action (*Ameiurus*), by pressure due to the action of the respiratory muscles (*Fundulus*), or it may be a part of the true respiratory current (*Mustelus*).

2. By means of this current dissolved substances in the water are brought into contact with the olfactory surfaces.

3. Fishes distinguish packets containing hidden food from similar packets without food.

4. This power of distinguishing the two classes of packets is lost when the olfactory tracts are cut, when the anterior olfactory apertures are stitched up or when the apertures are plugged with cotton wool. It is revived on reopening the apertures by taking out the stitches or removing the cotton wool.

Mustelus and *Ameiurus* discover their food chiefly through the olfactory sense; *Fundulus* uses the eyes in addition to the olfactory organs for this purpose.

6. *Mustelus*, *Fundulus*, and *Ameiurus* use the olfactory organs to scent food much as land animals do; these organs are true organs of smell, i. e., distance receptors for the chemical sense.

 POSTSCRIPT.

Since the preparation of this paper, confirmatory results have been obtained by Copeland (1912) on *Spheroides*, and our attention has been called to the earlier papers by Baglioni (1909, 1910) on *Balistes*, etc., in which, however, the reactions of the fishes are assumed, rather than proved, to be dependent upon the sense of smell.

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THE FISHES OF THE STREAMS TRIBUTARY TO
MONTEREY BAY, CALIFORNIA



By John Otterbein Snyder
Stanford University, California

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By JOHN OTTERBEIN SNYDER,
Stanford University, California.



INTRODUCTION.

The present paper deals with the fishes of the streams tributary to Monterey Bay, Cal. It contains a systematic record of the species, a discussion of their relationships, and an attempt to account for their present distribution. It involves some of the results of a prolonged investigation of western fluvial fishes which has been based primarily on material collected by agents of the United States Bureau of Fisheries. In connection with this study the writer has on several occasions visited the principal streams flowing into Monterey Bay, each time making observations and preserving specimens of the fishes. The early work was under the direction of Dr. Charles H. Gilbert, and assistance in the field was ably rendered by Dr. J. M. Stowell, Messrs. Wilfred H. Osgood and James A. Gunn. In the summer of 1909 the writer, assisted by Messrs. Willis H. Rich and Carl H. Gilbert, students of Stanford University, made a more complete survey of the system and collected large series of specimens. The well-preserved material obtained at this time has been most useful in determining the characteristics of the Pajaro species.

A microscopic examination of the scales has in some cases revealed reliable specific characters, and photographic illustrations are given. The proportional measurements of specimens are recorded in hundredths of the length from tip of snout to end of last caudal vertebra. They were made with considerable care by means of dividers and a proportional scale. The drawings of fishes are by Mr. W. S. Atkinson.

THE STREAMS TRIBUTARY TO MONTEREY BAY.

The streams that flow into Monterey Bay diverge from the coast like the fingers from the palm of one's hand. Beginning with the most northern, they occur in the following order: San Lorenzo River, Soquel Creek, Aptos Creek, Pajaro River, and Salinas River. Soquel and Aptos Creeks are of minor importance, as they drain very small basins and are subject to considerable desiccation during periods of long drought.

The San Lorenzo is a typical mountain stream. It drains a part of the moist western slopes of the Santa Cruz Ranges, flowing through canyons the steep sides of which are covered with trees and shrubs. Its water is clear and cool and is of large volume even during the dry season. Throughout its course the more rapid portions are broken by numerous quiet pools and broad, shallow areas with sandy or pebbly bottoms.

The Pajaro River receives the drainage from a large interior valley, flows through a narrow gorge which breaks transversely across a low range of the Coast Mountains, and enters the narrow valley which borders Monterey Bay. Its principal tributaries are Uvas and Llagas Creeks from the Santa Cruz Mountains on the northwest, San Felipe Creek from the dry Mount Hamilton Ranges on the east, and the San Benito River, which drains an elongate valley extending from southeast to northwest between the Mount Hamilton Ranges and the Gabilan Mountains. The upper courses of the Uvas and Llagas and parts of the San Benito flow through rather sparsely wooded mountain valleys. The San Benito is an uncertain and torrential stream, subject to great floods in the winter. It joins the Pajaro just before the latter enters the narrow gorge in the mountains, and brings in such quantities of sand and gravel that the Pajaro, unable to clear its channel, is so thoroughly choked up that there is no apparent current for several miles above the obstruction. Just above its junction with the San Benito, the Pajaro is from 12 to 15 feet deep, the submerged and dying branches of willows along its banks furnishing evidence of a recent rise in the water. There are indications that a shallow lake once covered an extensive area in the upper Pajaro Valley, Soap Lake, a mere pond being all that now remains of it. The lower Pajaro is a shallow stream, winding here and there over the sandy floor of a broad channel with high banks.

Salinas River flows through an elongate, narrow, and very deep valley which extends in the same general direction as the coast. Its course is parallel with that of the San Benito, from which it is separated by the Gabilan Mountains, a high and barren watershed. Between the valley of the Salinas and the ocean are the well-wooded Santa Lucia Mountains, from which the Salinas receives its principal water supply through the Arroyo Seco, San Antonio, and Nacimiento Creeks. The San Antonio and Nacimiento drain an extensive mountain area and pass down through deep canyons nearly parallel with the Salinas, presenting the very unusual case of tributaries flowing in a direction opposite to that of the main river. In their upper courses these creeks have a considerable volume of clear, cool water, which in summer is either largely consumed in irrigation or disappears in the parched sands and gravels of the valley below. The Salinas itself is an erratic and torrential stream. During the dry season its feeble current shifts here and there over broad stretches of wind-blown sand, entirely disappearing at times and again rising to the surface. After the advent of the winter rains, however, it presents a broad expanse of seething water which often threatens everything before it.

The streams tributary to Monterey Bay, which may be more briefly referred to as the Pajaro system, were described as diverging from the coast, when properly speaking they converge toward it. The mouths of the Pajaro and Salinas are in close proximity,

less than 3 miles of land separating them. The San Lorenzo flows into the bay at some distance north of the Pajaro, there being between their mouths more than 15 miles of coast, much of which is high, ascending rapidly to the foothills and the mountains beyond.

THE RELATIONSHIPS AND DISTRIBUTION OF THE FISHES.

The fishes of the Pajaro system may be said to belong to two fairly distinct groups. In the first of these may be assembled the anadromous forms and others which descend freely to salt water. They are the lampreys, trout, salmon, sticklebacks, and cottoids (*Entosphenus tridentatus*, *Salmo irideus*, *Oncorhynchus tshawytscha*, *O. kisutch*, *Gasterosteus cataphractus*, *Cottus asper*, *C. gulosus*, and *C. aleuticus*). Since the ocean presents no barrier to the dispersal of these species they have a wide distribution along the coast, occurring in all the streams of sufficient volume to support them.

To the second category belong the fresh-water fishes, the suckers, minnows, sunfish, and viviparous perch (*Catostomus mniotiltus*, *Orthodon microlepidotus*, *Ptychocheilus grandis*, *Hesperoleucus subditus*, *Lavinia ardesiaca*, *Agosia carringtoni*, *Archoplites interruptus*, and *Hysterocarpus traski*). These fishes are regarded as being strictly fluvial—not able to withstand long immersion in salt water. This assumption, though not based on experimental evidence, appears to be sufficiently established to accept without further discussion. Hence these species, living in isolated basins like those of the Pajaro or Salinas, occupy positions almost exactly analogous to those of reptiles or mammals inhabiting oceanic islands.

The present study shows that the fluvial fishes of the Pajaro system are all representatives of Sacramento River forms. In fact five of them, *O. microlepidotus*, *P. grandis*, *A. carringtoni*, *A. interruptus*, and *H. traski*, appear to be identical with Sacramento species, no distinctive local peculiarities having been observed among them. On the other hand, representatives of the Sacramento forms, *Catostomus occidentalis*, *Hesperoleucus venustus*, and *Lavinia exilicauda*, have become measurably differentiated, and so modified that they may be regarded as distinct species which are characteristic of the Pajaro system. The Pajaro basin alone contains a complete representation of the fluvial fauna of the region. The Salinas has six species, *C. mniotiltus*, *O. microlepidotus*, *H. subditus*, *L. ardesiaca*, *A. carringtoni*, and *H. traski*; the San Lorenzo three, *C. mniotiltus*, *H. subditus*, and *A. carringtoni*. Soquel and Aptos Creeks, which at times nearly dry up, have no fresh-water fishes at all.

If the relationships of the Pajaro fauna have been correctly determined, then one may safely pass to the conclusion that the Pajaro system received its species from the Sacramento,^a and it may further be assumed that there was once an open passage between them, or an intermingling of their waters which enabled fishes to migrate from one basin to the other. The Sacramento, not the Pajaro, is thought to be the region from which the migration took place, as it contains not only a full representation of the

^a There are no fluvial species in the coastal streams between the San Lorenzo River and the Golden Gate, nor are there any in the rivers immediately south of the mouth of the Salinas.

Pajaro fauna, but other species besides, and also because it is many times larger, and in the opinion of geologists it is considerably older.

In a recent study of the topography of a district including part of the Pajaro basin, Dr. J. C. Branner^a discovered unmistakable evidences of a former shifting of the channel of Coyote Creek, a stream of the Sacramento drainage basin, whereby its upper portion was for a time transferred to the Pajaro drainage. Coyote Creek drains the upper (southern) part of Santa Clara Valley, which is prolonged for a considerable distance southward as the San Benito Valley, the two being separated by a low divide which crosses obliquely from the southeast to the northwest. The Coyote has its origin in the mountainous district south of Mount Hamilton and has attained considerable size when it breaks from the range through a narrow gorge to enter the valley from the east. It passes near the divide just mentioned, turns abruptly northward and continues its course directly to San Francisco Bay. On the southwest side of the divide Llagas Creek emerges from the mountains to the west, enters the valley and flows southward to the Pajaro. The relative positions of these streams are shown on the map, plate XIX. Speaking of Coyote Creek, Dr. Branner says:

From the mouth of the gorge where this creek debouches on the plain a great alluvial fan spreads out toward the south and west across the entire width of the Santa Clara Valley, at this place a distance of $2\frac{1}{2}$ miles. This fan forms the watershed in the valley trough between the Bay of San Francisco and the Pajaro River or the Bay of Monterey.^b The configuration of the materials of the alluvial fan at the mouth of the gorge shows that the Coyote has been shifting its channel of late. A terrace south of the stream, and approximately parallel with it, shows that it formerly flowed toward the west, while another and still higher terrace farther south shows that at an earlier date it flowed toward the southwest; and the general form of the alluvial fan shows that the whole fan was built by the Coyote. It is a characteristic feature of streams, in the building up of such deposits, that they swing from side to side, flowing down over their own deposits in every direction, and shifting their channels as they become choked up by the deposit of their excess of load. The depth and position of the channel through which the Coyote now flows after emerging from the hills show that there has been no recent discharge of its waters toward the Pajaro. The general topography of the region about the mouth of the gorge suggests that the alluvial fan was built up a long while ago, and at a period when the stream was much more active than it now is—possibly during or toward the close of the glacial epoch. During the glacial epoch the streams of the region were much more vigorous than they have been since, for the coast stood at an elevation of two thousand or more feet higher than it does at present. There was therefore a greater precipitation, and during the winter months the Mount Hamilton Range must have been covered with snow which accumulated more than it does now and went off rather suddenly with the warm rains of early spring, producing much greater floods than we now have. It follows from the form of the alluvial fan on the plain where the stream emerges from the mountains that the Coyote must have shifted from side to side in the usual fashion, especially in the early history of the alluvial cone and during the constructive period. It flowed sometimes toward the northwest, draining into the Bay of San Francisco, and at other times toward the southeast, draining through the Pajaro into the Bay of Monterey.

The fishes of the Coyote are like those of the Sacramento, the stream itself being a part of the Sacramento system, the salt water of San Francisco Bay not being a constant barrier to the free passage of fishes from stream to stream along its shores. If a portion

^a Branner, J. C.: A drainage peculiarity of the Santa Clara Valley affecting fresh-water faunas. *Journal of Geology*, vol. xv, 1907, no. 1, p. 1-10, fig.

^b This alluvial fan is indicated by dotted lines on the map, plate XIX.

of the Coyote was at one time turned into the Pajaro, it must have carried its species into that basin where, meeting no competitors, they probably multiplied and spread with great rapidity. This account may be accepted as an explanation of the presence of Sacramento species in the Pajaro Basin. It may also be invoked to explain the absence of a complete representation of the Sacramento fauna, as only such species as were present in the upper portion of the Coyote would have been introduced into the Pajaro. The capture of the upper Coyote does not of itself account for the occurrence of some or even any of these species in the San Lorenzo or Salinas, the basins of which are separated from that of the Pajaro by an apparently impassable barrier of ocean water. This difficulty is seemingly surmounted by a further consideration of the geological history of the region as pointed out by Dr. Branner in a reference to the work of Prof. George Davidson.^a In his paper Davidson describes many submerged valleys that have been discovered by means of numerous soundings along the coast. After considering Monterey Bay and remarking that one would naturally expect the whole bay to be occupied by a 100-fathom plateau, he continues:

Nevertheless a remarkable submerged valley * * * runs across this plateau and heads into a low-lying country immediately behind the 30 miles of shore line of Monterey Bay. It reaches into the middle of this low line of beach near the mouth of the Salinas River, and the 50-fathom line is within less than half a mile of the shore. The valley which runs east and west is narrow, and at 7 miles from the shore the 100-fathom curves are only 2 miles apart and the depth 350 fathoms where the 50-fathom would be normal. It broadens and at 11 miles has a depth of 615 fathoms. From its northern edge a short, deep valley reaches to the northwest, but the 50-fathom curve of this arm is 5 miles from the shore.

Attention may now be directed to a map constructed from a Coast and Geodetic Survey chart of Monterey Bay, plate xx, where various soundings have been connected by contour lines, thus outlining the great valley or gorge described by Davidson. Such a valley could have been formed only by stream erosion, and its presence plainly points to a time when the bed of Monterey Bay was entirely exposed and the shore line extended beyond the present 600-fathom contour. Dr. Branner believes that the formation of the alluvial fan by the Coyote was coincident with this period of elevation of the coast, which brought about a climate of greater humidity than we now have and a correspondingly large amount of stream activity. At this time the Salinas was probably the chief river of the system, and flowing down the great valley, received first the Pajaro and then the San Lorenzo from the narrow canyons which extended toward the northeast. There was then an open waterway between the rivers of the Pajaro system and any species which might chance to be introduced from the Coyote by a shift of its headwaters would soon extend its range throughout the system.

It will now be recalled that of the streams tributary to Monterey Bay, the Pajaro alone contains a full representation of the fluvial fauna of the system. The Salinas contains six species and the San Lorenzo three. The question at once arises, if these streams, being of similar character and of about the same volume, were once connected with the Pajaro, why do they not now contain all its species?

^a Proceedings California Academy Sciences, 3d ser., Geology, vol. 1, p. 73-103.

In attempting to present a plausible answer, reference is again made to the alluvial fan between the Santa Clara and San Benito Valleys. The growth of this great deposit, which swung the course of Coyote Creek from side to side, at one time into the Pajaro basin and at another into its former channel, was probably at the height of its activity near the time of the greatest coastal elevation, and then slowly ceased as the coast subsided. The lower course of the Coyote then, as at present, probably contained a fairly complete representation of the Sacramento fishes, it having direct connection with the river itself. The upper course would perhaps at no time harbor as many forms as the main channel, although any of its species might possibly be found there at periods of high water, and at the very time when a shifting of the channel would most likely occur.

The first transfer of the Coyote was presumably made when the shore of Monterey Bay was near the present 600-fathom contour, and the San Lorenzo was consequently a tributary of the Pajaro. This inflow of foreign water brought with it three species,^a those which now inhabit the San Lorenzo and the Salinas, and all which at that particular time were contained in the captured portion of the Coyote. These forms eventually occupied the entire system, appearing in all its tributaries. The same cause which first turned the Coyote from its original channel would by its continued operation tend to shift it back again, leaving the Pajaro to itself as before. A subsidence occurring at this juncture drove the coast line back, submerging the lower part of the great valley, thus completely and permanently isolating the San Lorenzo with its three fluvial species. Again, the continued deposition of material on the plain where the Coyote emerged from the mountains turned its headwaters toward the Pajaro, bringing with it additional species, which easily reached the Salinas, but were barred from the San Lorenzo. Although the upper Coyote may have continued to swing back and forth over its growing alluvial fan, no other species succeeded in passing until by the continued subsidence of the coast and the consequent retreat of the shore line the Salinas was finally detached from the Pajaro. Further shifting of the stream over the alluvial fan enabled other species to enter the Pajaro, but the Coyote at last returned to its original channel before representatives of all its native fishes had succeeded in crossing the watershed.

It is especially significant that of the fishes which were presumably first transferred to the Pajaro, and which have consequently been longest isolated from the parent basin, three have become sufficiently differentiated to be regarded as distinct species.

^a No account is taken of the possibility of the introduction of species which later became extinct, for the reason that the volume of the San Lorenzo and all other conditions of the river and its surroundings appear favorable to the support of at least some of the species not found there. It should be mentioned in this connection, however, that somewhat similar cases of unequal distribution do occur, in the streams tributary to San Francisco Bay, for example, for which no acceptable reason seems to present itself. The chance that species living in the basin have been overlooked is ignored also, because of the careful collecting that has been done in the region.

It is barely possible that a close connection may at one time have existed between the Pajaro and Salinas Rivers, which was not mentioned in discussing those streams. On an examination of the map, plate xxx, or on an inspection of the coast between the mouths of the Pajaro and Salinas, evidence appears which seems to indicate that the mouths of both streams, and especially that of the Salinas, are subject, or have been subject, to considerable shifting. This shifting is due directly to the piling up of drift sand, which in the case of the Salinas has apparently been crowding the mouth of the river northward until it is now in comparatively close proximity to that of the Pajaro. It is conceivable that this same movement may continue until a union of the two streams takes place, and moreover one should not entirely overlook the possibility that such a union may have occurred before, and that the Salinas may even have received thereby a complete representation of the Pajaro fauna, certain species of which have since become extinct in that basin.

If the migration of these fishes from their native basin was accomplished during the glacial epoch or near its close, we have here a possible indication of the vast amount of time necessary for the appearance in nature of a slight amount of differentiation, for the Pajaro forms which have been described as distinct species differ only in a small degree from the parent forms of the Sacramento.

TABLE SHOWING DISTRIBUTION OF SPECIES IN THE PAJARO SYSTEM.

	<i>Entosphenus tridentatus.</i>	<i>Catostomus minifilius.</i>	<i>Orthodon microlepidotus.</i>	<i>Lavinia ardesiaca.</i>	<i>Ptychocheilus grandis.</i>	<i>Hesperoleucus subditus.</i>	<i>Agosia carringtoni.</i>	<i>Salmo irideus.</i>	<i>Oncorhynchus tshawytscha.</i>	<i>Oncorhynchus kisutch.</i>	<i>Gasterosteus cataphractus.</i>	<i>Archoplites interruptus.</i>	<i>Hysteroecarpus traski.</i>	<i>Cottus asper.</i>	<i>Cottus aleuticus.</i>	<i>Cottus gulosus.</i>
San Lorenzo Basin:																
San Lorenzo junction, Kings Creek.								X								
San Lorenzo junction, Boulder Creek.	X															
San Lorenzo at Brookdale.		X														
San Lorenzo near Felton.		X					X									
San Lorenzo near Big Trees.		X				X										
San Lorenzo near Santa Cruz.	X	X					X	X	X	X						X
Soquel Creek.											X					
Aptos Creek.								X			X			X	X	
Pajaro Basin:																
San Felipe near San Felipe.		X		X	X											
Pajaro between Sargent and San Felipe.		X		X	X											
Pajaro at Sargent.	X	X	X	X	X	X		X			X		X	X		
Pajaro above junction with San Benito.		X	X	X	X						X		X			
Pajaro at junction with San Benito.		X	X	X	X			X			X		X			
Pajaro below junction with San Benito.		X	X	X	X			X			X		X			
Pajaro 3 miles above Watsonville.	X	X	X	X	X			X			X		X			
Pajaro near Watsonville.		X	X	X	X			X			X		X			
Pajaro at Watsonville.		X	X	X	X			X	X		X		X	X		
Pajaro 1 mile below Watsonville.		X	X	X	X			X			X		X	X		
Llagas Creek in mountains.		X	X	X	X	X		X			X		X			X
Llagas Creek in mountains.		X	X	X	X	X		X			X		X			X
Llagas Creek in mountains.		X	X	X	X	X		X			X		X			X
Llagas Creek near mouth.		X	X	X	X	X		X			X		X			X
Uvas Creek in mountains.		X	X	X	X	X		X			X		X			X
Uvas Creek in mountains.		X	X	X	X	X		X			X		X			X
San Benito near San Benito.		X	X	X	X	X		X			X		X			
San Benito near Erie.		X	X	X	X	X		X			X		X			
San Benito near Hollister.		X	X	X	X	X		X			X		X			
San Benito near mouth.		X	X	X	X	X		X			X		X			
Tres Pinos Creek near Tres Pinos.		X	X	X	X	X		X			X		X			
Tres Pinos Creek at Tres Pinos.		X	X	X	X	X		X			X		X			
Salinas Basin:																
Salinas at San Miguel.		X	X	X		X					X					
Salinas at Bradley.		X	X	X		X	X				X					
Salinas at King.		X	X	X		X					X					
Salinas between Soledad and King.		X	X	X		X					X					
Salinas at Soledad.		X	X	X		X					X					
Salinas at Gonzales.		X	X	X	X	X		X			X			X		
Salinas near Spencers.		X	X	X		X		X			X			X		
Salinas near Salinas.	X	X	X	X		X		X			X		X			
Salinas near Spreckles.		X	X	X		X		X			X		X			
Salinas near Blanco.		X	X	X		X		X			X		X			
Nacimiento Creek in foothills.		X	X	X		X		X			X		X			X
Nacimiento Creek in mountains.		X	X	X		X		X			X		X			X
Nacimiento Creek in mountains.		X	X	X		X		X			X		X			X
San Antonio Creek near Mission.		X	X	X		X		X			X		X			
San Antonio in mountains.		X	X	X		X		X			X		X			
Arroyo Seco 1 mile above mouth.		X	X	X		X		X			X		X			
Arroyo Seco 2 miles above mouth.		X	X	X		X		X			X		X			
Arroyo Seco 4 miles above mouth.		X	X	X		X		X			X		X			
Arroyo Seco 6 miles above mouth.		X	X	X		X		X			X		X			X

SYSTEMATIC DISCUSSION OF SPECIES.

Entosphenus tridentatus (Gairdner). *Three-toothed lamprey.*

Lampreys have been taken in the San Lorenzo, Pajaro, and Salinas Rivers. They appear in large numbers in the San Lorenzo during the month of March. Young examples may be found during the summer (May-July) burrowing like earthworms in the soil of the river banks below the water line. A dead adult specimen was found in Nacimiento Creek July 16.

Catostomus mniotiltus, new species. *Pajaro sucker.*

This form, a representative of *Catostomus occidentalis*, the coarse-scaled sucker of the Sacramento system, differs from the parent species principally in having larger scales in the anterior dorsal region of the body. This difference, visible on a careful comparison of specimens from both river systems, is well illustrated by enumerating the series of scales between the occiput and dorsal fin and also between the lateral line and middle of back.

Scales above lateral line.....	10	11	12	13	14	15	16	17							
Specimens <i>C. occidentalis</i>.....	.....	.....	.....	11	24	36	25	5							
Specimens <i>C. mniotiltus</i>	13	66	31	6	.....	.....	.....	.....			
Scales before dorsal.....	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Specimens <i>C. occidentalis</i>.....	.....	.....	.....	.....	.....	.....	3	11	12	23	15	10	12	13	1
Specimens <i>C. mniotiltus</i>	2	6	16	18	27	23	16	7	1	.....	.....	.....	.....	.....	.....

The mouth is smaller and the lips narrower in *C. mniotiltus*, and the body appears to be more robust and stalky.

This species is not closely related to *C. microps* Rutter, of the Sacramento, the relationships of the latter being with the fine-scaled suckers *C. rimiculus* of the Klamath and *C. catostomus* of the Columbia.

Description of the type, no. 74465, United States National Museum, from Arroyo Seco Creek, Monterey County, Cal. Length, 208 millimeters.

Head 4.8 in length to base of caudal; depth 4.8; depth caudal peduncle 2.6 in head; eye 6; interorbital space 2.3; snout 2; dorsal rays 12; anal rays 7; scales in lateral line 57; between lateral line and middle of back 11; between lateral line and insertion of ventral 8; between occiput and insertion of dorsal fin 27.

The head is short and broad, the body deep and stocky; interorbital area very convex; width of mouth contained 5 times in head; upper lip with about 5 rows of papillæ; cleft of lower lip so deep that not more than 1 row of papillæ lies between it and the border of mouth; inner border of lips smooth and somewhat horny; about 4 rows of minute papillæ between valve and upper border of mouth. Length of fontanelle equal to diameter of orbit. Origin of dorsal midway between tip of snout and base of caudal; highest rays 1.5 in head, not nearly reaching tips of last rays in depressed fin. Ventrals inserted beneath middle of dorsal, their length 1.7 in head, the edges rounded. Anal 1.5 in head. Caudal lobes slightly shorter than head. Pectorals rather obtusely pointed, 1.4 in head.

Scales large and regular. Lateral line almost straight excepting a short curve immediately behind upper edge of gill opening. A row of mucous pores passes from near tip of snout, beneath and behind eye, then curves upward and turns backward to join the lateral line at upper edge of gill opening, from where it is connected with the opposite side of head by a similar row of pores across the occiput; another row of pores extends from occipital row forward above eye and near edge of nostril to near tip of snout.

Color in spirits, dark on the upper surfaces, growing lighter below the lateral line; the ventral area white. Scales of the dark areas with dusky basal spots and narrow dark margins. Dorsal, caudal, and pectorals suffused with dusky color; ventrals and anal immaculate. In life the upper parts are dark olive, the sides with brassy and silvery reflections. Young individuals have a dark spot on the

operele, a similar one immediately behind the head, a third on middle of sides above base of ventrals, and a fourth on caudal peduncle. These spots enable one to identify young suckers at a glance when they are swimming among individuals of other species.

This appears to be the most widely distributed fluvial species in the Pajaro system. It is represented in each basin by large numbers of individuals which frequent all parts of the streams, living along with the trout in the cool, rapid creeks of the mountains, appearing in the warm, shallow ripples of the valleys, and thriving especially well in deep, turbid pools where algae and diatoms are abundant. Specimens may be seen in the brackish water near the mouths of the rivers, and they survive to the last in the detached pools of a desiccating stream.

Measurements of 20 specimens follow.

MEASUREMENTS OF TWENTY SPECIMENS OF CATOSTOMUS MNIOTILTUS.

Arroyo Seco Creek.

Length of body mm.	200	220	205	198	148	152	128	124	123	122
Length head	0.24	0.245	0.25	0.245	0.24	0.25	0.25	0.25	0.25	0.25
Depth body . . . . .	.25	.245	.25	.26	.22	.225	.25	.235	.25	.23
Depth caudal peduncle . . . . .	.09	.095	.095	.095	.09	.09	.09	.09	.085	.09
Length caudal peduncle . . . . .	.15	.15	.15	.16	.16	.15	.15	.165	.16	.15
Length snout . . . . .	.12	.125	.12	.13	.12	.12	.12	.13	.12	.12
Diameter eye . . . . .	.045	.04	.04	.04	.04	.045	.045	.045	.05	.045
Interorbital width . . . . .	.10	.10	.10	.105	.10	.10	.10	.10	.10	.10
Depth head . . . . .	.175	.18	.18	.185	.19	.18	.18	.18	.18	.18
Snout to occiput . . . . .	.21	.21	.21	.21	.22	.22	.21	.23	.22	.22
Snout to dorsal . . . . .	.52	.52	.52	.52	.515	.52	.53	.53	.54	.54
Snout to ventral . . . . .	.565	.57	.59	.59	.585	.57	.57	.59	.58	.59
Length base of dorsal . . . . .	.165	.17	.16	.17	.17	.17	.16	.16	.16	.16
Length base of anal . . . . .	.08	.08	.075	.08	.075	.075	.075	.075	.075	.07
Height dorsal . . . . .	.17	.165	.165	.17	.18	.17	.17	.17	.18	.18
Height anal . . . . .	.18	.17	.165	.165	.16	.16	.16	.15	.17	.17
Length pectoral . . . . .	.19	.20	.19	.18	.18	.19	.18	.18	.20	.20
Length ventral . . . . .	.15	.15	.14	.145	.14	.14	.15	.13	.14	.15
Length caudal . . . . .	.22	.22	.21	.22	.23	.23	.21	.23	.23	.24
Dorsal rays	12	12	12	12	13	12	11	12	11	12
Anal rays	8	7	7	7	8	7	7	7	7	8
Scales lateral line	60	61	60	57	62	61	60	58	57	63
Scales above lateral line	11	12	11	12	11	11	12	11	12	12
Scales below lateral line	8	9	9	9	8	8	8	8	8	8
Scales before dorsal	26	27	27	26	26	27	26	27	28	28

Pajaro River, Watsonville.

Length of body mm.	162	144	133	134	128	135	121	116	107	111
Length head	0.24	0.25	0.26	0.24	0.25	0.235	0.24	0.25	0.25	0.23
Depth body . . . . .	.20	.21	.22	.245	.22	.20	.23	.20	.22	.21
Depth caudal peduncle . . . . .	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09
Length caudal peduncle . . . . .	.15	.155	.15	.16	.15	.16	.16	.15	.15	.15
Length snout . . . . .	.12	.11	.125	.12	.12	.12	.11	.12	.11	.12
Diameter eye . . . . .	.04	.045	.045	.045	.05	.045	.05	.05	.05	.05
Interorbital width . . . . .	.10	.095	.10	.10	.10	.09	.10	.10	.09	.095
Depth head . . . . .	.17	.165	.17	.175	.18	.17	.17	.17	.18	.17
Snout to occiput . . . . .	.22	.21	.22	.21	.22	.20	.21	.21	.22	.21
Snout to dorsal . . . . .	.52	.51	.53	.51	.52	.51	.54	.51	.52	.51
Snout to ventral . . . . .	.58	.57	.58	.56	.59	.575	.59	.59	.58	.59
Length base of dorsal . . . . .	.17	.16	.17	.18	.16	.16	.16	.16	.17	.16
Length base of anal . . . . .	.075	.07	.08	.085	.08	.08	.07	.07	.08	.08
Height dorsal . . . . .	.18	.18	.20	.18	.19	.19	.20	.18	.20	.19
Height anal . . . . .	.17	.16	.19	.18	.16	.17	.17	.16	.18	.17
Length pectoral . . . . .	.19	.20	.21	.20	.19	.20	.20	.20	.20	.20
Length ventral . . . . .	.16	.15	.165	.16	.16	.15	.16	.16	.17	.16
Length caudal . . . . .	.23	.23	.245	.23	.23	.23	.24	.24	.25	.24
Dorsal rays	12	12	11	12	12	11	11	12	11	12
Anal rays	7	7	7	7	7	8	7	7	7	7
Scales lateral line	58	62	62	57	61	59	59	57	60	60
Scales above lateral line	12	11	12	11	12	12	13	12	12	12
Scales below lateral line	10	10	10	9	9	8	9	8	8	8
Scales before dorsal	26	27	27	25	28	29	29	28	29	29

Orthodon microlepidotus (Ayres). *Blackfish*.

This is a channel fish frequenting the deep pools and never appearing in the smaller creeks. In the Pajaro Basin it does not seem to occur in large numbers. It has not been seen in the San Lorenzo and it has been taken but once in the Salinas, Dr. Gilbert and Dr. Stowell having collected specimens near San Miguel.

The dorsal rays number from 9 to 11; the anal 8 or 9; scales in lateral line 94 to 102; below lateral line 12 or 13; above lateral line 23 to 25; between occiput and dorsal 49 to 54.

The following measurements are from specimens collected at Watsonville.

MEASUREMENTS OF SPECIMENS OF *ORTHODON MICROLEPIDOTUS*.

Length of body.....mm.	184	190	200	195	202	185	189	182
Length head.....	0.25	0.26	0.27	0.26	0.26	0.26	0.255	0.27
Depth body.....	.245	.235	.225	.22	.22	.24	.23	.245
Depth caudal peduncle.....	.08	.08	.085	.08	.08	.08	.08	.09
Length caudal peduncle.....	.21	.21	.19	.21	.20	.21	.22	.21
Length snout.....	.08	.085	.09	.09	.09	.085	.085	.09
Diameter eye.....	.04	.045	.04	.04	.04	.045	.04	.045
Interorbital width.....	.10	.11	.115	.11	.11	.105	.11	.11
Depth head.....	.17	.17	.175	.165	.16	.17	.17	.175
Snout to occiput.....	.20	.19	.20	.20	.20	.21	.19	.21
Snout to dorsal.....	.52	.515	.535	.515	.52	.53	.53	.54
Snout to ventral.....	.52	.535	.535	.545	.54	.53	.535	.54
Length base of dorsal.....	.15	.17	.155	.145	.15	.15	.14	.135
Length base of anal.....	.11	.11	.10	.115	.10	.105	.10	.10
Height dorsal.....	.19	.185	.215	.19	.175	.20	.19	.205
Height anal.....	.16	.16	.165	.155	.15	.17	.16	.17
Length pectoral.....	.17	.18	.17	.19	.16	.21	.165	.175
Length ventral.....	.18	.17	.18	.18	.155	.185	.16	.17
Length caudal.....	.265	.26	.28	.26	.25	.28	.27	.27
Dorsal rays.....	10	11	10	9	10	10	10	10
Anal rays.....	8	8	8	8	8	8	8	8
Scales lateral line.....	94	94	100	102	101	95	100	102
Scales above lateral line.....	25	23	25	23	25	24	23	24
Scales below lateral line.....	13	13	13	13	13	13	13	13
Scales before dorsal.....	52	52	51	49	54	50	49	51

Lavinia ardesiaca, new species. *Silver minnow*.

Minnows of this type found in the Pajaro system differ from *Lavinia exilicauda* of the Sacramento River in having fewer dorsal and anal rays, a somewhat heavier and less compressed body, and in other peculiarities.

In *L. ardesiaca* the dorsal rays are usually 9 or 10 in number, most often 10, while in *L. exilicauda* they number from 10 to 12, most often 11. The anal rays of *L. ardesiaca* number from 8 to 13, the maximum number of examples having 10; the same rays of *L. exilicauda* number from 11 to 14 with 13 as the most usual. These differences are well illustrated in the tables of measurements annexed to the description of the species.

Description of the type no. 74459, United States National Museum, from the Pajaro River near Watsonville, Cal. Length 287 millimeters. (Fig. 1, text.)

Head 4.7 in length to base of caudal; depth 4.4; depth caudal peduncle 2.7 in head; eye 5.4; interorbital space 2.5; snout 3.4; dorsal rays 10; anal rays 11; scales lateral line 59; between lateral line and middle of back 14; between lateral line and base of ventral 7; between occiput and insertion of dorsal 38.

Body of symmetrical proportions, the head small and pointed, the caudal peduncle slender and round; dorsal outline rising in a nearly even curve to middle of back and then sloping gently to caudal peduncle. Eye located considerably in advance of middle of head, but not entirely above a median lateral line. Angle of mouth not reaching a vertical through anterior edge of pupil. Gillrakers on first arch, 19; each being a long, triangular, sharply pointed flap, the posterior edge of which is denticulate.

Pharyngeal teeth (cotype) 5-5, long and compressed; the tips hooked, the grinding surface well developed, though narrow. Lips with a sharp-edged, horny covering (more conspicuous in larger individuals). Lateral line with a gentle downward curve in its anterior fourth. Dorsal inserted midway between pupil and base of caudal; height of longest (first) rays 1.3 in head; edge of fin nearly straight. Height of first anal rays 1.5 in head, the last ray half as high. Ventrals rounded; 1.5 in head; not reaching vent when depressed. Caudal deeply incised, the lobes rather pointed; about an eye's diameter longer than head. Pectoral 1.3 in head, the edge rounded.

Color dark above, lighter on sides, immaculate beneath; the dark color more intense on edges of scales and forming definite dark borders on those below lateral line. In life, olive on upper parts, silvery on the sides and beneath, the silvery color especially brilliant when reflecting the sunlight in the clear water.

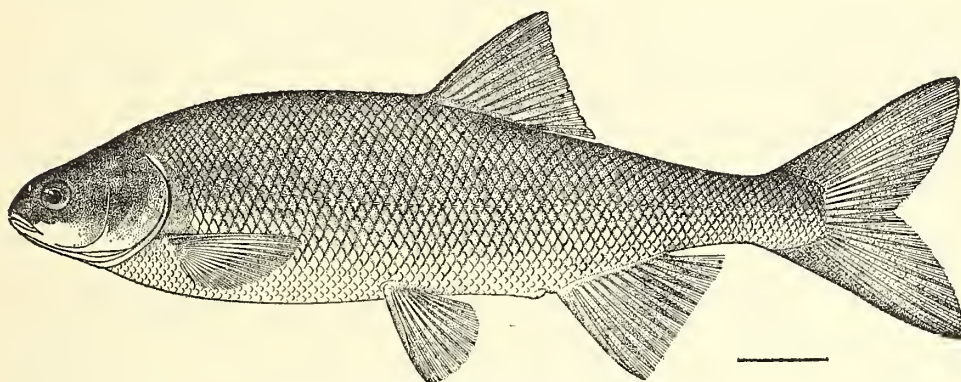


FIG. 1.—*Lavinia ardesiaca*, new species. Type.

NUMBER OF DORSAL AND ANAL RAYS IN SPECIMENS OF *LAVINIA ARDESIACA* AND *LAVINIA EXILICAUDA*.

Dorsal rays.....	8	9	10	11	12		
Specimens <i>L. ardesiaca</i>	2	49	80	9	1		
Specimens <i>L. exilicauda</i>			3	31	1		
Anal rays.....	8	9	10	11	12	13	14
Specimens <i>L. ardesiaca</i>	1	20	51	38	29	1	.....
Specimens <i>L. exilicauda</i>				1	8	25	1

The specimens of *L. exilicauda* referred to in the above tables are from Cache Creek and Putah Creek, tributaries of the Sacramento. However, the number of dorsal and anal rays here given appears to be fairly characteristic of examples of the species from various parts of its range, as is shown in a table published by Rutter^a and here introduced.

^a Rutter, Cloudsley: The fishes of the Sacramento-San Joaquin basin, with a study of their distribution and variation. Bulletin Bureau of Fisheries, vol. xxvii, 1907, p. 127.

VARIATION IN FIN RAYS OF *LAVINIA EXILICAUDA*.

Locality.	Number of specimens having—							
	Dorsal—				Anal—			
	10	11	12	13	11	12	13	14
Battle Creek hatchery.....		1	1				2	
Sacramento River:								
Red Bluff.....		2	2				4	
Chico.....		1	1	1			3	
Jacinto.....		7	3				7	2
20 miles below Grimes.....		1					1	
Feather River, Oroville.....			2				2	1
American River, Folsom.....			2				1	1
Antelope Creek, Feryn.....			2				1	1
Sacramento River, Rio Vista.....		1					1	
San Joaquin River, Black Diamond.....		1					1	
Merced River, Livingstone.....			5				5	
China Slough, Centerville.....		2	8			1	6	3
Kings River, Centerville.....		2	8		1	2	7	
Kaweah River, St. John Channel.....		6	4		1	1	7	1
Tule River, Porterville.....	2	2	1					
Total.....	2	26	39	1	2	4	48	8

With a decrease of the number of fin rays has come a consequent shortening of the bases of both dorsal and anal fins in *L. ardesiaca*.

DORSAL AND ANAL FIN MEASUREMENTS RECORDED IN HUNDREDTHS OF THE LENGTH TO BASE OF DORSAL.

Length base of dorsal.....	0.12	0.13	0.14	0.15	0.16	0.17	0.18	
Specimens <i>L. ardesiaca</i>	1	6	30	43	19	3		
Specimens <i>L. exilicauda</i>			2	5	23	4		1
Length base of anal.....	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18
Specimens <i>L. ardesiaca</i>	1	4	11	20	24	27	6	
Specimens <i>L. exilicauda</i>					1	4	12	14

Examples of this species are comparatively heavy in appearance, the body being somewhat less compressed than that of *L. exilicauda*, the snout a little longer, and the head somewhat larger. These differences, though slight and not easily shown by measurements, appear when a considerable series of specimens of both species pass under one's observation.

The structure of the scales (fig. 26, pl. xxiv) does not appear to differ materially from that of *L. exilicauda*. They are more or less spatulate in outline, the nuclear area elevated, the basomedian and basolateral ridges high and rounded, the apicolateral ridges very weak or entirely absent. There are neither basal nor lateral radii. The apical radii number as follows, 50 scales from 10 individuals having been examined:

First year, 5 to 10, usually 7 to 9.

Second year, 6 to 16, usually 11 to 14.

Third year, 9 to 22, usually 14 to 19.

Fourth year, 11 to 26, usually 16 to 23.

The species is found in the Pajaro and Salinas Basins, but appears to be absent from the San Lorenzo. It frequents the lower courses of the streams, delighting in the shallow water of the ripples, where large schools may be seen moving about over the yellow sand of the bottom in the full glare of the sun. The larger individuals, which are darker in color and less silvery than the smaller ones, take

refuge in the deep pools. The species is not well represented where the current is very rapid and where the water, cool and clear, plunges over and around the rocks and boulders. In the upper courses of the streams it is not found at all. It is seldom associated with *Hesperoleucus*.

The largest specimens caught measured 13 inches in length. They were taken with baited hook in the Pajaro. They do not appear to reach such proportions in the Salinas, the river being too shallow.

An examination of the scales of a number of individuals indicates that their growth is about as follows:

First year, 60 to 85 millimeters, about 3 inches.

Second year, 95 to 110 millimeters, about 4 inches.

Third year, 150 to 210 millimeters, about 7 inches.

Fourth year, 160 to 230 millimeters, about 8.5 inches.

Fifth year, — to 280 millimeters, about 10 inches.

Sixth year, 285 to 320 millimeters, about 12 inches.

Measurements of 20 specimens of this species follow and for comparison similar measurements of 10 examples of *L. exilicauda* are also given.

MEASUREMENTS OF 20 SPECIMENS OF *LAVINIA ARDESIACA*, NEW SPECIES.

Pajaro River, Watsonville.

Length of body.....mm.	162	166	133	118	112	114	100	86	84	93
Length head.....	0.235	0.235	0.23	0.24	0.245	0.24	0.24	0.24	0.25	0.25
Depth body.....	.28	.255	.27	.27	.265	.26	.25	.26	.275	.255
Depth caudal peduncle.....	.08	.075	.09	.085	.09	.09	.085	.08	.095	.09
Length caudal peduncle.....	.15	.16	.175	.15	.17	.16	.15	.165	.165	.17
Length snout.....	.07	.065	.07	.07	.07	.07	.065	.07	.075	.07
Diameter eye.....	.05	.05	.055	.055	.055	.05	.065	.055	.06	.055
Interorbital width.....	.085	.08	.085	.09	.085	.09	.08	.09	.095	.085
Depth head.....	.16	.155	.18	.18	.17	.17	.165	.18	.195	.18
Snout to occiput.....	.18	.175	.185	.19	.19	.185	.19	.20	.19	.20
Snout to dorsal.....	.575	.545	.56	.565	.57	.57	.56	.54	.58	.56
Snout to ventral.....	.525	.515	.51	.53	.51	.52	.50	.52	.53	.54
Length base of dorsal.....	.17	.155	.15	.15	.165	.15	.15	.17	.....	.15
Length base of anal.....	.16	.16	.155	.16	.145	.14	.16	.16	.15	.16
Height dorsal.....	.195	.195	.19	.21	.19	.20	.22	.21	.22	.21
Height anal.....	.18	.165	.17	.17	.165	.17	.18	.19	.185	.19
Length pectoral.....	.18	.17	.17	.17	.175	.17	.20	.185	.20	.18
Length ventral.....	.165	.16	.15	.165	.165	.16	.18	.16	.17	.17
Length caudal.....	.30	.275	.29	.30	.30	.29	.275	.31	.32	.32
Dorsal rays.....	11	10	10	10	10	10	11	10	10	10
Anal rays.....	11	11	11	11	11	11	12	11	10	12
Scales lateral line.....	60	54	55	55	54	54	54	55	57	54
Scales above lateral line.....	13	14	13	13	13	13	12	13	13	14
Scales below lateral line.....	6	6	6	7	6	6	6	6	6	6
Scales before dorsal.....	35	34	32	33	33	34	33	32	33	33

Salinas River, near Salinas.

Length of body.....mm.	163	121	94	90	75	90	86	79	73	81
Length head.....	0.24	0.25	0.25	0.24	0.255	0.24	0.26	0.245	0.25	0.25
Depth body.....	.28	.265	.255	.25	.30	.25	.27	.275	.265	.275
Depth caudal peduncle.....	.08	.09	.08	.085	.09	.09	.09	.09	.10	.10
Length caudal peduncle.....	.16	.14	.14	.165	.17	.165	.16	.16	.16	.15
Length snout.....	.07	.065	.065	.065	.07	.065	.07	.07	.08	.07
Diameter eye.....	.05	.06	.06	.06	.065	.065	.07	.07	.065	.165
Interorbital width.....	.09	.09	.09	.09	.09	.08	.085	.085	.08	.085
Depth head.....	.185	.19	.175	.17	.185	.17	.185	.18	.18	.19
Snout to occiput.....	.18	.20	.185	.19	.21	.20	.20	.20	.20	.20
Snout to dorsal.....	.59	.585	.59	.57	.58	.56	.575	.58	.57	.58
Snout to ventral.....	.525	.55	.555	.52	.54	.51	.55	.54	.53	.54
Length base of dorsal.....	.14	.15	.16	.15	.14	.15	.15	.15	.16	.15
Length base of anal.....	.16	.17	.15	.16	.14	.17	.145	.16	.17	.16
Height dorsal.....	.175	.19	.21	.21	.20	.20	.22	.225	.21	.205
Height anal.....	.165	.17	.17	.17	.18	.175	.18	.18	.18	.19
Length pectoral.....	.165	.17	.17	.18	.18	.175	.19	.19	.18	.20
Length ventral.....	.155	.16	.17	.16	.16	.17	.17	.175	.16	.17
Length caudal.....	.275	.31	.305	.31	.30	.28	.31	.325	.31	.295
Dorsal rays.....	10	10	11	11	10	10	10	10	11	10
Anal rays.....	12	12	12	12	11	12	11	11	12	12
Scales lateral line.....	57	56	60	56	60	57	57	55	59	55
Scales above lateral line.....	13	12	13	13	13	12	13	13	12	12
Scales below lateral line.....	6	6	6	6	6	6	6	6	6	6
Scales before dorsal.....	34	31	34	34	32	33	31	32	32	33

MEASUREMENTS OF 10 SPECIMENS OF LAVINIA EXILICAUDA.

Cache Creek, tributary of Sacramento River.

Length of body.....mm..	166	182	178	118	118	102	102	76	103	100
Length head.....	0.23	0.20	0.235	0.23	0.225	0.23	0.24	0.235	0.235	0.22
Depth body.....	.27	.24	.24	.265	.26	.27	.27	.26	.27	.26
Depth caudal peduncle.....	.08	.07	.07	.085	.08	.09	.09	.09	.08	.09
Length caudal peduncle.....	.155	.135	.17	.155	.155	.165	.16	.175	.17	.17
Length snout.....	.06	.055	.065	.065	.06	.065	.06	.06	.065	.055
Diameter eye.....	.05	.045	.05	.06	.06	.06	.06	.06	.065	.055
Interorbital width.....	.085	.075	.08	.08	.08	.08	.08	.08	.08	.08
Depth head.....	.17	.16	.16	.17	.16	.17	.16	.17	.17	.175
Snout to occiput.....	.17	.17	.18	.18	.18	.19	.185	.19	.19	.19
Snout to dorsal.....	.565	.59	.56	.58	.57	.57	.60	.58	.57	.55
Snout to ventral.....	.51	.54	.52	.515	.535	.52	.53	.51	.51	.50
Length base of dorsal.....	.16	.145	.16	.165	.16	.165	.16	.16	.16	.16
Length base of anal.....	.17	.175	.16	.17	.18	.17	.16	.165	.18	.175
Height dorsal.....	.20	.17	.185	.21	.21	.23	.21	.23	.20	.235
Height anal.....	.17	.16	.17	.185	.17	.19	.18	.20	.18	.195
Length pectoral.....	.17	.16	.155	.18	.18	.19	.185	.195	.185	.19
Length ventral.....	.16	.16	.16	.175	.17	.185	.17	.18	.18	.18
Length caudal.....	.29	.27	.30	.32	.33	.305	.32	.36	.32	.33
Dorsal rays.....	11	11	11	11	11	11	11	11	11	11
Anal rays.....	13	14	12	12	13	12	13	13	13	12
Scales lateral line.....	57	59	62	56	58	58	57	58	58	58
Scales above lateral line.....	14	14	13	14	13	13	12	13	13	13
Scales before dorsal.....	37	35	37	38	38	35	35	34	34	36

Ptychocheilus grandis (Ayers). Sacramento pike.

P. grandis^a occurs in the Pajaro Basin, but is not found in either the San Lorenzo or Salinas. It is the largest of the Pajaro minnows. Specimens measuring 20 inches in length were caught in the deep pools. Although a channel fish, it appears to venture up the smaller tributaries farther than *Lavinia* or *Orthodon*, but is not able to extend its range with *Hesperoleucus* or *Catostomus*.

A table of measurements is appended.

MEASUREMENTS OF SPECIMENS OF PTYCHOCHEILUS GRANDIS.

Length of body.....mm..	196	220	295	226	177	164	146	141	158	164
Length head.....	0.27	0.27	0.265	0.265	0.27	0.26	0.27	0.28	0.27	0.265
Depth body.....	.195	.205	.205	.195	.20	.22	.19	.19	.19	.20
Depth caudal peduncle.....	.09	.09	.095	.09	.09	.09	.08	.085	.08	.085
Length caudal peduncle.....	.195	.21	.19	.20	.19	.195	.19	.19	.18	.20
Length snout.....	.095	.09	.095	.095	.09	.09	.09	.09	.095	.095
Diameter eye.....	.04	.04	.035	.04	.045	.045	.045	.045	.05	.05
Interorbital width.....	.08	.075	.075	.075	.08	.075	.075	.08	.07	.08
Depth head.....	.14	.145	.135	.15	.14	.145	.14	.14	.15	.15
Snout to occiput.....	.21	.205	.20	.21	.21	.22	.21	.21	.22	.21
Snout to dorsal.....	.56	.56	.55	.56	.59	.59	.57	.58	.575	.57
Snout to ventral.....	.54	.545	.535	.55	.545	.55	.56	.555	.55	.54
Length base of dorsal.....	.105	.11	.115	.10	.12	.115	.11	.10	.11	.10
Length base of anal.....	.09	.95	.10	.09	.105	.95	.10	.10	.95	.95
Height dorsal.....	.175	.175	.165	.165	.175	.18	.175	.175	.18	.17
Height anal.....	.155	.16	.145	.155	.16	.16	.165	.15	.16	.165
Length pectoral.....	.15	.17	.14	.145	.15	.16	.15	.155	.16	.165
Length ventral.....	.13	.14	.14	.125	.14	.14	.135	.14	.145	.14
Length caudal.....	.24	.24	.235	.225	.24	.245	.24	.235	.245	.26
Dorsal rays.....	9	9	8	8	8	8	8	8	8	8
Anal rays.....	9	9	9	9	9	9	9	9	9	9
Scales lateral line.....	74	72	73	74	76	73	71	74	73	75
Scales above lateral line.....	15	14	14	14	15	15	13	14	13	14
Scales below lateral line.....	7	7	7	8	7	8	7	7	8	8
Scales before dorsal.....	36	40	36	38	39	36	38	41	39	41

^a *Ptychocheilus rapax* Girard, said to have been collected at Monterey, Cal., is apparently a synonym of *P. grandis* and doubtless owed its assigned locality to a confusion of labels. A similar case is *Mylocheilus fraterculus* Girard taken by the same collector and also said to have come from Monterey. This is *M. lateralis* (*M. caurinus* of recent authors), the only known species of the genus, and does not occur south of the Columbia River.

HESPEROLEUCUS, new genus.

The generic name *Hesperoleucus* is here used for a small group of closely related cyprinoid fishes previously included with others in the genus *Rutilus* or *Myloleucus*. The species of *Hesperoleucus* have the insertion of the dorsal fin posterior to the ventrals, by which character they may be distinguished from *Myloleucus*. They also have a shorter head, more slender body, and a more nearly horizontal lower jaw. The pharyngeal teeth number 4-5, 4 on the right side, with a narrow but well-developed grinding surface. *Hesperoleucus symmetricus* may stand as the type of the genus.

Hesperoleucus is a genus peculiar to the Sacramento River fauna. Its species inhabit the smaller tributaries of the rivers that flow into the Sacramento and San Joaquin, some of the coastal streams north of the Golden Gate, the creeks tributary to San Francisco Bay, and the rivers flowing into Monterey Bay. They have been included in the species *Rutilus symmetricus* by recent authors, as were also several forms belonging to the genus *Myloleucus*. The latter is an assemblage of comparatively large lake and channel fishes which do not usually frequent the smaller creeks, but live mainly in the deep, sluggish pools of the rivers. They occur abundantly in certain lakes of the Great Basin, where they grow to a large size.

In a previous paper^a the writer referred to three well-defined geographic races of *Hesperoleucus* (*Rutilus*) thus: "A minnow of this type occurs in the Navarro, Gualala, Russian, and Napa Rivers. Specimens from the Russian and Napa Rivers are alike in all respects, and they in turn agree closely with representatives from the streams tributary to San Francisco Bay. In a majority of cases the dorsal fin has 9 rays and the anal 8. The snout is rather pointed, the caudal peduncle slender, and the fins long, the whole body being trim and well proportioned. Examples from the Navarro and Gualala Rivers are distinguished from these by having generally 8 rays in the dorsal fin, a more robust body, with a deeper caudal peduncle, and a more rounded and shortened snout. The fins are also shorter and somewhat less acute. While examples from the Navarro and Gualala Rivers thus agree in differing from specimens taken in the neighboring basins, individuals from each of these streams bear a distinctive local stamp by which they may be recognized without difficulty, the Navarro examples having mostly one more ray in the anal fin, and larger scales in the series above the lateral line. It has been shown that individuals from the partly isolated rivers tributary to San Francisco Bay are alike in all points, and that these are scarcely to be distinguished in any particular from individuals from the Napa and Russian Rivers. Hence it appears that there are three well-differentiated forms of *Rutilus* in this somewhat restricted region, each of which occupies a distinct hydrographic basin or series of contiguous basins. When, however, the field is broadened and specimens from distant parts of the Sacramento and San Joaquin Basins are brought together, similar variations of a local nature are found to occur, but whether any geographical significance may be attached to these can not be known until more extensive observations have been made." Since then more material has been secured, including specimens of *H. symmetricus* from the type locality, and many examples of a well-differentiated form from the streams tributary to Monterey Bay. In order to deal intelligently with the latter it now seems best to restrict the name *symmetricus* to fishes of the genus inhabiting the rivers of the San Joaquin Valley, to recognize the form frequenting the streams in the immediate region of San Francisco Bay, and likewise that of the Navarro River, Gualala River, and of the streams tributary to Goose Lake, descriptions of which follow in the order indicated.

Hesperoleucus symmetricus (Baird and Girard)^a is not to be confused with *Algansea formosa* Girard, *Algansea obesa* Girard, *Myloleucus pulverulentus* Cope, nor *Myloleucus parovanus* Cope. This species,

^a Snyder, J. O.: The fishes of the coastal streams of Oregon and northern California. Bulletin Bureau Fisheries, vol. xxvii, 1907, p. 175.

^b Jordan and Evermann: Fishes North and Middle America, Bulletin 47, U. S. National Museum, p. 246, synonymy of *Rutilus symmetricus*. Through the kindness of the National Museum authorities the writer has been permitted to examine the types of *Pogonichthys symmetricus* Baird and Girard, and also of *Algansea formosa* Girard. The latter, which is from Merced River, and in a bad state of preservation, appears to be indistinguishable from *Myloleucus thalassinus* of the upper Pit River and Goose Lake. It is a *Myloleucus*, not a *Hesperoleucus*, and if when better specimens from the Merced are examined no differentiating characters appear, *M. formosa* will stand in place of *M. thalassinus*, its known range extending from the lower San Joaquin to the northern tributaries of Goose Lake.

represented by specimens collected by Mr. Rutter near the type locality, San Joaquin River at Polasky, is a form characterized by large eyes, long head, and pointed snout, a symmetrical body with narrow caudal peduncle, and long fins. There are 9 rays in the dorsal, 8 in the anal.^a The scales in the lateral line number from 47 to 53. A specimen 85 millimeters in length to base of caudal exhibits the following proportional measurements: Length of head, .27; depth of body, .24; depth of caudal peduncle, .10; length of snout, .09; diameter of eye, .07; interorbital width, .105; snout to dorsal, .585; snout to ventrals, .53; length of base of dorsal, .16; anal, .19; length of pectoral, .20; caudal, .32; scales in lateral line, 51; above lateral line, 13; below lateral line, 6; before dorsal, 30. Scales which appear to be typical are illustrated (fig. 1, 2, 3, and 4). The apical radii number from 13 to 22, 15 to 20 representing the usual number in individuals 2 or 3 years old. Lateral radii sometimes appear, but they are usually absent.

No exact data are at hand concerning the species of *Hesperoleucus* inhabiting the great rivers tributary to the Sacramento, and but little is known of those distributed throughout the valley of the San Joaquin.

Hesperoleucus venustus, new species. *Venus roach*.

This form inhabits the Russian River, the streams entering San Pablo, Suisun, and San Francisco Bays. It is characterized chiefly by long fins, a comparatively pointed snout, and slender caudal

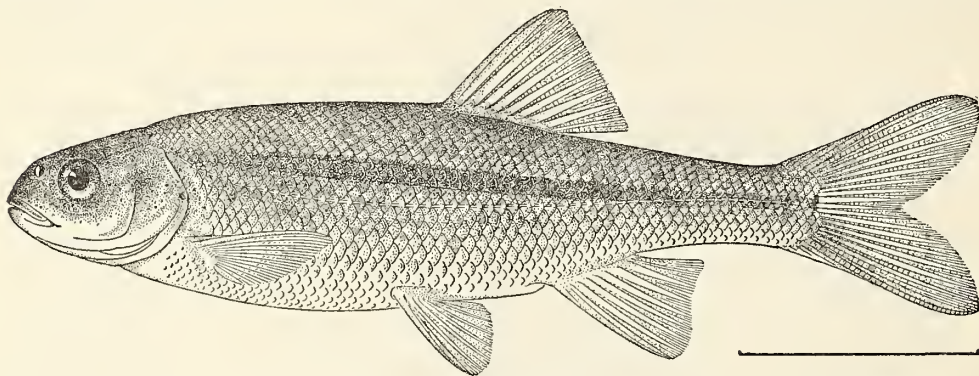


FIG. 2.—*Hesperoleucus venustus*, new species. Type.

peduncle, the whole body being trim and well proportioned. The dorsal and anal rays number 9 and 8, respectively.

Description of the type, no. 74476 United States National Museum, from Coyote Creek near Gilroy Hot Springs, Cal. Length, 107 millimeters (fig. 2):

Head 4.1 in length to base of caudal; depth 3.9; depth of caudal peduncle 2.5 in head; eye 4; interorbital space 2.7; snout 3; dorsal 9; anal 8; scales in lateral line 53; between lateral line and middle of back 13; between lateral line and origin of ventrals 7; between occiput and origin of dorsal 30.

Body slender, the caudal peduncle narrow, head small, snout short and rather bluntly rounded; eye not included in anterior half of head nor entirely above a median line through body; mouth reaching a vertical which passes a little anterior to orbit. Gillrakers on first arch 10, very short, pointed and widely spaced. Pharyngeal teeth (cotypes) 4-5, 4 on the right side, occasionally 5-5 or 4-4; grinding surface narrow, equal in width to the tooth; tips of teeth hooked. Lateral line with a gentle downward curve on anterior half. Origin of dorsal midway between posterior border of eye and base of caudal; anterior ray 1.3 in head, its tip when depressed not reaching as far posteriorly as that of last ray; edge

^a Rutter (op. cit., Bulletin Bureau Fisheries, vol. xxvii, p. 138) records 10 rays in the dorsal and 9 in the anal, but an examination of some of his specimens shows that he is in the habit of enumerating the last ray as 2 when it is deeply cleft, i. e., branched.

of fin slightly concave. First anal ray 1.3 in head; edge of fin concave. Ventrals rounded, not reaching anal. Pectoral equal in length to height of dorsal; obtusely pointed. Caudal deeply cleft, the lobes acutely rounded.

Color in spirits dusky above, light beneath, the sides and under parts silvery; a narrow, light stripe extending from upper edge of gill opening to base of caudal; beneath this a conspicuous black stripe, narrow in front, somewhat wider behind, the color deepest above anal fin; several very indistinct, narrow, dark stripes beneath lateral line.

The scales are more or less quadrangular, rounded or spatulate in shape. (Fig. 5-10, pl. XXI and XXII.) The basolateral angles are prominent, and the apicolateral angles weak or entirely obliterated. There are no basal radii, and lateral radii are rarely present except in specimens from the Russian River. The apical radii number from 8 to 21, usually 10 to 18. There are from 50 to 61 scales in the lateral line, counts of a series of specimens resulting as follows:

Scales lateral line.....	50	51	52	53	54	55	56	57	58	59	60	61
Number of specimens.....	1	6	4	6	14	28	26	22	15	20	13	3

In this character it differs from *H. symmetricus*, which has from 47 to 53. It differs further from the same species in having smaller eyes and a shorter head. Measurements of many specimens have been made and published.^a

At least one isolated basin, the Russian River, is included in the region occupied by this form, and specimens from it are somewhat peculiar. The trim, slender form characteristic of the species reaches its highest development here, and the scales usually have from 1 to 5 lateral radii. (Fig. 10, pl. XXII.) Specimens from Napa River also show slight local peculiarities, but neither these nor those from the Russian River appear to differ very much from individuals from the streams flowing into San Francisco Bay.

H. venustus appears to be the parent form of *H. navarroensis* and *H. parvipinnis*, they having become differentiated through the agencies accompanying complete isolation. It will be noted on referring to the descriptions of these species that lateral radii are present on the scales of both, and that in this respect they resemble individuals of *H. venustus* from the Russian River. The distribution of *H. venustus* in the Sacramento basin is unknown.

Hesperoleucus navarroensis, new species. *Navarro roach*.

This is a species inhabiting the Navarro Basin on the western coast of northern California. It is distinguished by its robust body, deep caudal peduncle, short snout, and rounded fins, and in having 8 rays in the dorsal and anal fins. This form is closely allied to *H. parvipinnis*, the one evidently derived from the other or both from one parent stock. *H. navarroensis* differs from *H. parvipinnis* in the number of anal fin rays and in having generally 1 less row of scales above the lateral line.

Description of the type, no. 74477, United States National Museum, from Navarro River near Philo, Cal. Length 90 millimeters.

Head 3.6 in length to base of caudal; depth 3.6; depth caudal peduncle 2.2 in head; eye 4.2; inter-orbital area 2.8; snout 3.1; dorsal rays 8; anal rays 8; scales lateral line 56; between lateral line and middle of back 13; between lateral line and origin of ventral 7; between occiput and origin of dorsal 30.

Body deep, particularly in the caudal region; posterior margin of eye behind a median vertical through head; lower border of eye somewhat below median line of body. Gillrakers on first arch 8, very short and stumpy. Pharyngeal teeth (cotypes) 4-5, 4 on the right side; a grinding surface equal to width of tooth; the tips slightly hooked. No material variation appears in the teeth of a number of

^a Snyder, J. O.: Op. cit., Bulletin Bureau Fisheries, vol. XXVII, 1907, p. 176; Notes on the fishes of streams flowing into San Francisco Bay, Appendix to Report Commissioner of Fisheries for 1904, p. 332, *Rutilus symmetricus*.

individuals. Lateral line with a slight downward curve on anterior part of body. Origin of dorsal midway between center of pupil and base of caudal; height of longest rays contained 1.4 times in head; border of fin straight; rays all reaching an equal distance posteriorly when depressed. Ventrals inserted a little anterior to dorsal, the tips reaching anal opening, the edges rounded. Anal 1.7 in head, the edge straight. Caudal deeply incised, the lobes rather pointed, equal in length to head. Pectorals rounded, 1.2 in head.

Color in spirits, dark brown above, lighter and with a silver reflection below; a straight stripe about 2 scales wide extending from upper edge of gill opening to base of caudal, entirely above lateral line; below this a dark stripe, somewhat wider, and then a series of narrow, light and dark stripes which become less distinct ventrally and finally disappear.

Of 72 specimens examined, 68 had 8 anal rays, 3 had 7, and 1 had 9, while all had 8 dorsal rays. There are usually from 51 to 59 scales in the lateral line and 11 to 13 above it. The scales (fig. 11-13) are generally spatulate in form, mostly longer than broad; the apical edge very convex or even pointed, lateral edges usually sloping somewhat toward apex, basal edge double concave with a rather pronounced median prolongation which is the base of a strong median ridge; basolateral ridges prominent, apicolateral ridges more or less indistinct; apical region of scales located notably near the basal edge; basal slope abrupt; apical slope gentle. Basal radii absent; lateral radii weak and irregular, sometimes absent on one or both sides, numbering from 1 to 5; apical radii 14 to 24, usually 16 to 20.

Measurements of a series of 10 specimens of this species are given in "The Fishes of the Coastal Streams of Oregon and Northern California" (Snyder, Bulletin of the Bureau of Fisheries, vol. xxvii p. 177, *Rutilus symmetricus* near Philo, Cal.).

***Hesperoleucus parvipinnis*, new species. Short-finned roach.**

This form, found in the Gualala River basin, is characterized by the robust body, deep caudal peduncle, short snout, short, rounded fins, and by having 8 and 7 rays in the dorsal and anal fins.

Description of the type, no. 74466, United States National Museum, Gualala River, Sonoma County, Cal. Length 83 millimeters.

Head 3.9 in length to base of caudal; depth 3.9; depth caudal peduncle 2.2 in head; eye 4.2; inter-orbital space 2.8; snout 3; dorsal 8; anal 7; scales in lateral line 59; between lateral line and middle of back 13; between lateral line and origin of ventral 8; between occiput and origin of dorsal 30.

Body deep, the caudal peduncle deep and heavy; eye not altogether in anterior part of head, and projecting a little below a median line alongside of body. Gillrakers on anterior arch 8, very short and stumpy. Pharyngeal teeth (cotypes) 4-5, 4 on the right side, the grinding surface no wider than the main shaft of the tooth; well defined hooks present. No variation appeared on an examination of the teeth of a number of specimens. Anterior third of lateral line with a gentle downward curve, the remainder straight. Origin of dorsal midway between posterior margin of eye and base of caudal fin; anterior rays highest, 1.4 in length of head, falling somewhat short of tips of posterior rays in depressed fin. Ventrals inserted anterior to a vertical through origin of dorsal, reaching anal opening when depressed, their edges rounded. Anal 1.5 in head; rounded. Caudal deeply emarginate, the lobes rounded; the length slightly less than that of head. Pectoral rounded, 1.2 in head.

Color in spirits dusky above, lighter below; a light lateral stripe two scales wide extending from upper edge of gill opening to base of caudal and entirely above lateral line; below this a somewhat wider dark stripe, which in turn is followed by several narrower and very distinct dark stripes which grow lighter ventrally.

In 80 specimens of *H. parvipinnis*, 70 had 7 anal rays, 9 had 8, and 1 had 6, all having 8 dorsal rays. There are usually from 54 to 59 scales in the lateral line, and 14 to 16 rows above it. The scales (fig. 14-16, pl. xiii) are rather small, usually somewhat longer than broad, generally quadrangular, the apical and basal edges not very strongly convex; lateral edges almost parallel. Spatulate examples are not rare. The apical slope gentle, basal slope abrupt; basolateral ridges prominent, the others well marked. No

basal radii present; lateral radii weak and few in number, 1 to 4; often absent; apical radii 11 to 24, usually 13 to 19.

Measurements of a series of specimens are recorded in the paper above referred to. (Snyder, Bulletin of the Bureau of Fisheries, vol. XXVII, p. 177, *Rutilus symmetricus*.)

Hesperoleucus mitrulus, new species. *Northern roach*.

This name is proposed for the form found in the streams tributary to the north end of Goose Lake, a basin properly belonging to the Sacramento system, but practically separated from it. This species has not been reported from the turbulent streams that flow into Goose Lake from the mountains on the eastern side, nor has it been taken in the lake itself. It is characterized by the short dorsal and anal, 8 and 7 rays, respectively, by having the fins lower and shorter than those of related forms, and in the peculiar cup-like shape of the scales.

Description of the type, no. 74474 United States National Museum, from Drew Creek, Lake County, Oreg. Length, 84 millimeters.

Head 4.7 in length to base of caudal; depth 4.7; depth caudal peduncle 2.4 in head; eye 4.6; interorbital area 3; snout 3; dorsal rays 8; anal rays 7; scales in lateral line 60; between lateral line and middle of back, 14; between lateral line and origin of ventral, 8; between occiput and origin of dorsal, 37.

Body rather deep and heavy, perhaps a little more slender than that of *M. navarroensis* or *M. parvipinnis*; snout short and rounded; eye entirely within anterior part of head, and not quite above a median lateral line of body. Gillrakers of first arch, 9; very small. Pharyngeal teeth (cotypes), 4-5, 4 on the right side; a grinding surface about equal in width to the shaft of tooth; small hooks at tips. Lateral line with a gentle downward curve on anterior half. Insertion of dorsal midway between center of pupil and base of caudal, the height about 1.6 in head, the edge rounded; ventrals inserted anterior to dorsal, the edges rounded, not reaching vent when fin is depressed. Anal rounded posteriorly; 1.8 in head. Caudal deeply incised, the lobes rounded; slightly longer than head. Pectorals rounded; 1.7 in head.

Color in spirits dark brown above, lighter beneath; no dark pigment on the ventral surface. A light stripe 2 scales wide passing from upper edge of gill opening to base of caudal, entirely above lateral line; beneath this a conspicuous dark stripe which is narrowed to a line anteriorly, nearly 3 scales broad posteriorly; sides anteriorly with several very narrow and indistinct dark stripes.

When examined under the microscope, the scales (fig. 17-20, pl. XXIII) are seen to be very convex, almost conical, usually though not always rounded, the basal edge scalloped. They are small in size, there being 54 to 61 in lateral series, 32 to 38 before the dorsal, and 12 to 15 above the lateral line. Basal radii are present in large number, and they are distinct and strong, occasionally entering the nuclear area of the scale. They number from 8 to 17, usually 12 to 15. The ridges of the scales being scarcely developed, there is no sharp line of demarkation between apical, lateral, or basal regions. The apical radii number from about 13 to 20, usually 15 to 18; lateral radii 3 to 9, generally 4 to 6 or 7. Measurements of 20 examples of this species were published in the paper previously referred to. (Snyder, Bulletin of the Bureau of Fisheries, vol. XXVII, p. 98, *Rutilus symmetricus*.)

Hesperoleucus subditus, new species. *Monterey roach*.

This species is related to *H. venustus* of Coyote Creek and other streams tributary to San Francisco Bay. It differs in having a somewhat more robust body, slightly shorter fins, fewer dorsal and anal rays, and a smaller number of scales in the lateral line.

Description of the type, no. 74475, United States National Museum, from Uvas Creek, Pajaro River basin, Santa Clara County, Cal. Length, 110 millimeters. (Fig. 3.)

Head 3.8 in length to base of caudal; depth 3.6; depth caudal peduncle 2.3 in head; eye 4.4; interorbital area 2.6; snout 3.1; dorsal rays 8; anal rays 7; scales in lateral line 53; between lateral line and middle of back 14; between lateral line and origin of ventral 7; between occiput and origin of dorsal 28.

Body markedly robust, deep and heavy, the caudal peduncle especially so; head rather blunt, the snout rounded; eye just within anterior half of head and entirely above median line of body; angle of mouth reaching a vertical which passes a little anterior to orbit. Gillrakers on first arch 9, very short and blunt. Pharyngeal teeth (of cotypes) 4-5, 4 on the right side; a narrow grinding surface on each tooth, a slight hook near the tip. An examination of 10 individuals shows no material variation in the character of the teeth. Lateral line curved downward to a point above insertion of ventrals from where it is more or less straight to base of caudal. Origin of dorsal midway between center of pupil and end of last caudal vertebra; the 2 anterior rays highest, 1.25 in head; their tips falling somewhat short of those of posterior rays when fin is depressed. Ventral inserted a little anterior to dorsal, the point of insertion being midway between nostril and base of caudal; edge of fin rounded; not quite reaching anal opening when depressed. Anterior rays of anal longest, equal to those of dorsal; reaching beyond tips of posterior rays in depressed fin. Caudal emarginate, the lobes broadly rounded and about equal; somewhat longer than head. Pectoral rounded, 1.3 in head.

Color in spirits, dark above, light below; a faint, light stripe about 2 scales wide extending from upper edge of gill opening alongside of body to base of caudal, the stripe being straight and lying entirely above the lateral line; beneath this a series of narrower and very indistinct alternating light and dark

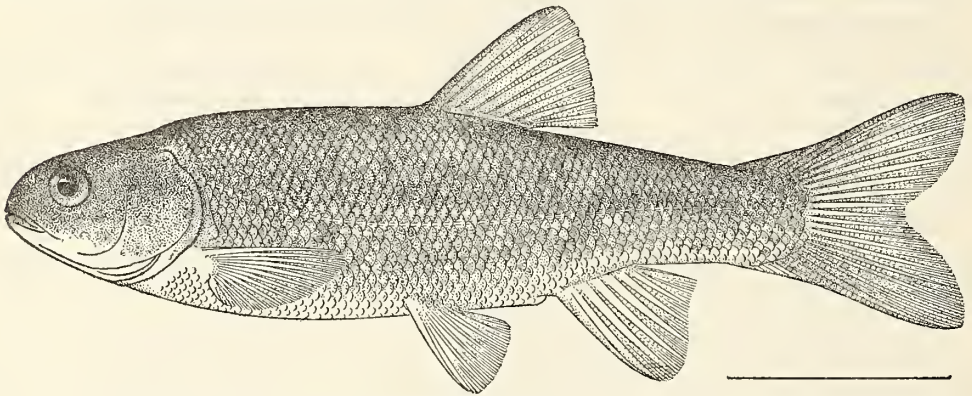


FIG. 3.—*Hesperoleucus subditus*, new species. Type.

stripes. In life deep olive above, whitish beneath, the transition appearing below the lateral line; a silvery pigment appearing on the lighter areas.

The number of dorsal rays is typically 8, the anal 7. Occasionally examples have 7 or 9 dorsal rays, and a few specimens have 8 anal rays. The following table will serve to illustrate the variation of fin rays:

Number of specimens examined.	Dorsal rays.			Anal rays.	
	7	8	9	7	8
205.....	9	194	2	187	18

Among the 18 examples tabulated as having 8 anal rays 13 were taken from the same pool in the Pajaro at Sargent.

The scales appear to be larger than those of *H. venustus*, and there are consequently a lesser number in the lateral series, the difference, an average one, appearing in the annexed table.

Lateral series of scales.....	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Number of specimens, Pajaro system.....	1	2	14	10	14	26	28	18	16	8	1	1	.....	2
Number of specimens, San Francisco Bay system.....	1	2	3	3	12	24	15	18	11	14	8	2		

There is nothing distinctive in the shape of the scales (fig. 21-25, pl. xxiv), but on the contrary they exhibit a great variety of forms, none of which, however, is peculiar to any particular region. They are usually rather oblong, although rounded or quadrangular specimens may be found. Some are spatulate and others have the edges rather straight and nearly parallel. The nuclear area is distinctly basal in location, and the basolateral angles are pronounced. The apicolateral angles are usually weak or absent. The apical radii vary from 12 to 25, the usual number being from 15 to 21 in examples 2 or 3 years old, the radii increasing with age, as may be seen on examining the illustrations.

Number of apical radii.....	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Number of specimens.....	1	9	13	21	36	45	48	34	29	25	11	2	3	1

Lateral radii are present in nearly all cases, the scales in this regard differing markedly from those of *M. venustus*. The lateral radii number from 1 to 8, 1 to 5 or 6 being the most usual. There are no basal radii.

This species has about 36 vertebrae, in this respect not differing from related forms. Of 10 specimens from the Pajaro, 8 had 36 vertebrae, while the others had 35 and 37, respectively. In a similar series of *M. venustus* from Isabel Creek, Santa Clara County, 8 had 36 vertebrae and 2 had 37.

M. subditus is generally distributed in the Pajaro system, living in such portions of the streams as flow through the foothills and lower mountain ranges. It does not frequent the upper, turbulent parts of the creeks, nor is it often found in the low valleys where the water is shallow and the bed sandy.

MEASUREMENTS OF SPECIMENS OF *HEPEROLEUCUS SUBDITUS*, NEW SPECIES.

Length of body.....mm..	Salinas Basin.									
	Salinas River near Gonzales.					Arroyo Seco Creek.				
	77	74	80	75	75	89	87	85	78	70
Length head.....	0.27	0.25	0.27	0.27	0.26	0.26	0.25	0.27	0.26	0.28
Depth body.....	.25	.24	.24	.26	.26	.26	.24	.26	.26	.27
Depth caudal peduncle.....	.11	.11	.11	.11	.11	.10	.10	.11	.11	.11
Length caudal peduncle.....	.23	.23	.22	.21	.22	.22	.21	.20	.21	.20
Length snout.....	.09	.085	.09	.09	.09	.08	.08	.09	.08	.08
Diameter eye.....	.06	.06	.06	.06	.06	.06	.06	.07	.06	.07
Interorbital width.....	.09	.09	.09	.09	.09	.08	.09	.085	.09	.09
Snout to occiput.....	.185	.18	.18	.19	.19	.18	.20	.19	.18	.20
Snout to dorsal.....	.22	.20	.22	.21	.21	.20	.20	.22	.21	.21
Snout to ventral.....	.57	.55	.59	.55	.60	.58	.56	.58	.58	.59
Length base of dorsal.....	.52	.51	.53	.54	.54	.52	.52	.54	.55	.52
Length base of anal.....	.11	.12	.12	.135	.115	.13	.12	.12	.12	.12
Height dorsal.....	.10	.09	.11	.11	.09	.10	.11	.10	.10	.10
Height anal.....	.21	.19	.16	.16	.20	.16	.17	.18	.19	.18
Length pectoral.....	.26	.18	.16	.17	.175	.16	.15	.16	.17	.15
Length ventral.....	.26	.23	.19	.20	.20	.19	.18	.20	.19	.18
Length caudal.....	.18	.16	.14	.15	.16	.15	.13	.15	.14	.14
	.30	.25	.26	.27	.29	.24	.25	.25	.24	.24
Dorsal rays.....	7	8	8	8	8	8	8	8	8	8
Anal rays.....	7	7	7	7	7	8	7	7	7	7
Scales lateral line.....	53	54	51	53	53	50	54	50	53	55
Scales above lateral line.....	13	14	12	14	13	13	14	14	13	13
Scales below lateral line.....	7	8	7	7	7	7	7	7	7	7
Scales before dorsal.....	29	31	30	28	28	27	30	30	31	28

MEASUREMENTS OF SPECIMENS OF *HESPEROLEUCUS SUBDITUS*, NEW SPECIES—Continued.

	Pajaro Basin.										San Lorenzo Basin.				
	Pajaro River at Sargent.					Uvas Creek.					San Lorenzo River.				
Length of body.....mm.	79	74	70	63	60	91	84	88	76	77	65	64	62	55	57
Length head.....	0.24	0.25	0.26	0.26	0.26	0.25	0.24	0.26	0.25	0.26	0.27	0.26	0.28	0.26	0.27
Depth body.....	.26	.25	.25	.26	.28	.26	.25	.27	.27	.26	.26	.24	.27	.27	.28
Depth caudal peduncle.....	.10	.11	.11	.11	.12	.12	.11	.12	.12	.11	.12	.11	.11	.12	.12
Length caudal peduncle.....	.22	.22	.21	.22	.23	.23	.22	.22	.22	.23	.22	.23	.22	.23	.22
Length snout.....	.08	.09	.09	.09	.08	.08	.08	.08	.09	.085	.08	.08	.08	.09	.08
Diameter eye.....	.06	.05	.06	.06	.07	.05	.06	.06	.06	.06	.06	.06	.065	.065	.065
Interorbital width.....	.10	.085	.085	.08	.09	.09	.09	.10	.10	.10	.10	.09	.09	.09	.10
Depth head.....	.18	.18	.18	.20	.20	.18	.19	.19	.20	.19	.20	.22	.20	.20	.20
Snout to occiput.....	.20	.21	.20	.21	.22	.20	.20	.20	.20	.21	.23	.21	.22	.23	.22
Snout to dorsal.....	.57	.54	.57	.57	.58	.57	.57	.55	.56	.57	.58	.57	.58	.59	.58
Snout to ventral.....	.53	.52	.51	.52	.52	.52	.52	.53	.51	.51	.53	.53	.53	.53	.54
Length base of dorsal.....	.13	.12	.13	.13	.12	.13	.13	.13	.14	.14	.12	.12	.12	.12	.13
Length base of anal.....	.12	.10	.12	.12	.10	.11	.11	.10	.10	.11	.10	.10	.10	.10	.10
Height dorsal.....	.19	.20	.20	.21	.19	.19	.20	.20	.20	.18	.18	.20	.18	.19	.20
Height anal.....	.17	.17	.17	.19	.18	.17	.18	.18	.18	.18	.16	.16	.16	.18	.19
Length pectoral.....	.19	.19	.19	.21	.23	.20	.20	.20	.19	.20	.18	.20	.19	.24	.21
Length ventral.....	.15	.15	.16	.16	.15	.16	.16	.16	.15	.16	.14	.14	.14	.15	.16
Length caudal.....	.28	.27	.27	.29	.27	.26	.28	.27	.28	.27	.25	.26	.25	.26	.27
Dorsal rays.....	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Anal rays.....	8	8	7	7	7	7	7	7	7	7	7	7	7	7	7
Scales lateral line.....	54	50	50	53	53	55	51	53	55	53	50	57	50	50	57
Scales above lateral line.....	15	15	14	14	13	13	14	15	15	15	14	14	15	14	16
Scales below lateral line.....	7	7	8	7	8	8	8	7	8	8	8	7	8	8	8
Scales before dorsal.....	32	30	31	31	30	29	30	29	32	32	31	32	30	30	32

Agosia carringtoni (Cope). *California dace*.

Specimens of *Agosia* taken in the Pajaro system do not appear to differ from those of the Sacramento.

Salmo irideus Gibbons. *Rainbow trout*.

The trout taken in the tributaries of the Pajaro system appear to belong to the native species, except a few specimens from the San Lorenzo River, which have larger eyes and a somewhat different color pattern. The native trout appear to agree in all details of structure and color with specimens from Coyote Creek and other streams tributary to San Francisco Bay. The young of other species have been introduced into various streams from time to time, but either none have been taken at the numerous collecting stations, or else the writer has failed to recognize them among the preserved specimens. It is possible, however, that the introduced forms of rainbow trout come to resemble the native species so closely that their identity would be difficult to detect. The dead bodies of large steelheads were occasionally seen in Uvas, Arroyo Seco, and Nacimiento Creeks. At high water they are said to enter all the streams in large numbers. They are frequently mistaken for salmon.

Small trout, beautiful in color and excellent in quality, abound in the upper courses of the creeks and rivers, and especially good fishing may be had in Nacimiento and San Antonio Creeks. The trout of the main channels of the rivers are apt to be rather poor in quality, and are usually light silvery in color. Occasionally a silvery specimen is taken among the darker colored examples of a tributary stream.

Oncorhynchus tshawytscha (Walbaum). *Chinook salmon*.

This species was reported from the San Lorenzo and Pajaro Rivers. No small salmon were taken with the seine at any collecting station.

Oncorhynchus kisutch (Walbaum). *Silver salmon*.

Silver salmon were said to have been observed in the San Lorenzo River at Santa Cruz.

Gasterosteus cataphractus (Pallas). *Stickleback*.

Sticklebacks appear in all the streams tributary to Monterey Bay. They usually have from 4 to 6 lateral plates, the sides being mostly naked and the caudal keel absent. Many fully plated examples were collected, however, these being found near the mouths of the rivers in close proximity to salt water.

An examination of the sticklebacks of this coast will scarcely bear out the conclusions of Mr. C. Tate Regan published in a recent paper.^a He finds that a circumpolar species *G. aculeatus* extends downward along our coast to the Santa Clara River, Cal., and then gives place to *G. santa-anae*, a species inhabiting the Santa Ana River, which reaches the ocean a few miles to the southward of the Santa Clara River. The distinctive characters assigned to *G. santa-anae* are (compared with *G. aculeatus*) sides of body without bony plates (rarely with 2 or 3 anteriorly); dorsal rays 10 or 11; anal rays 6 or 7 (8); origin of first dorsal spine well behind base of pectoral and only slightly in advance of base of pelvics, 29 vertebrae.

Some time ago Rutter^b showed that in the region between the Santa Ana River and San Francisco Bay all conditions of lateral armature from entirely naked to completely plated sides might be found. Rutter's notes show that of 111 specimens from the Santa Ana River at Riverside, 104 were naked, 4 had 1 plate, and 3 had 2 plates. Of 298 individuals from the Santa Clara River, 76 had no lateral plates, 41 had 1, 99 had 2, 67 had 3, and 15 had 4. These data seem sufficient to prevent differentiating the Santa Ana fishes on the character of lateral armature, and a perusal of Rutter's paper will demonstrate the futility of attempting to show that the sticklebacks of any locality on this coast may be distinguished by the number of plates on the sides of their bodies. The present writer^c examined about 2,000 specimens taken in the rivers between San Francisco Bay and the Columbia, and became convinced that within that region at least but one form could be recognized. The data at hand simply show that a larger proportion of naked examples have been collected in the Santa Ana River, but judging from what is known of the lateral armature of sticklebacks in other streams it would not be very hazardous to predict that further collecting in the Santa Ana would result in securing specimens that are more fully armed. That the Santa Ana fishes are not distinguished by peculiar fin structure is shown in an examination of 20 specimens selected at random from a collection from Santa Clara River, where 3 examples have 10, 13 have 11, and 4 have 12 dorsal rays; 5 have 7, 11 have 8, and 4 have 9 anal rays. The position of the first dorsal spine and also the number of vertebrae are likewise variable. In brief, no one seems able to find any characters or set of characters that will serve to differentiate the Santa Ana sticklebacks, or in fact those from any other river basin along the west coast. Perhaps it may be said that individuals of the species generally attain a larger size and a more complete armature in the north, while they are usually smaller and more scantily armed in the south; and also that while such a geographic variation obtains a similar one seems to appear which is coordinate with habitat, i. e., heavily plated individuals are more generally found in or near salt water, while the more nearly naked ones usually occur in the rivers at some distance from the ocean.

It seems better to retain the name *G. cataphractus* for west American sticklebacks until sufficient evidence shows that it is not tenable.

Archoplites interruptus (Girard). *Sacramento perch*.

Small sunfish were collected in the Pajaro at Sargent and near the junction of the Pajaro and San Benito. This species has not been reported from Coyote Creek nor any of the smaller streams tributary to San Francisco Bay.

Hysteroecarpus traski Gibbons. *Fresh-water viviparous perch*.

Frequently seen in the Pajaro and Salinas Rivers. Does not occur in the San Lorenzo.

^aRegan, C. Tate: The species of three-spined sticklebacks. *Annals and Magazine of Natural History*, ser. 8, vol. IV, p. 435.

^bRutter, Cloudsley: Notes on fresh-water fishes of the Pacific slope of North America. *Proceedings California Academy of Sciences*, 2d ser., vol. VI, p. 245-254.

^cSnyder, J. O., op cit., *Bulletin Bureau Fisheries*, vol. XXVII, 1907, p. 183.

Cottus asper Richardson. *Prickly bullhead.*

This species is a channel form, occurring in deep, quiet pools, and most often near the mouths of the rivers. It is easily caught with a baited hook. The following fin ray counts were made from specimens taken in the Pajaro River.

Spines or rays.....	Dorsal spines.			Dorsal rays.			Anal rays.		Pectoral rays.		
	7	8	9	19	20	21	16	17	15	16	17
Number of specimens.....	1	14	10	8	14	3	17	8	5	16	4

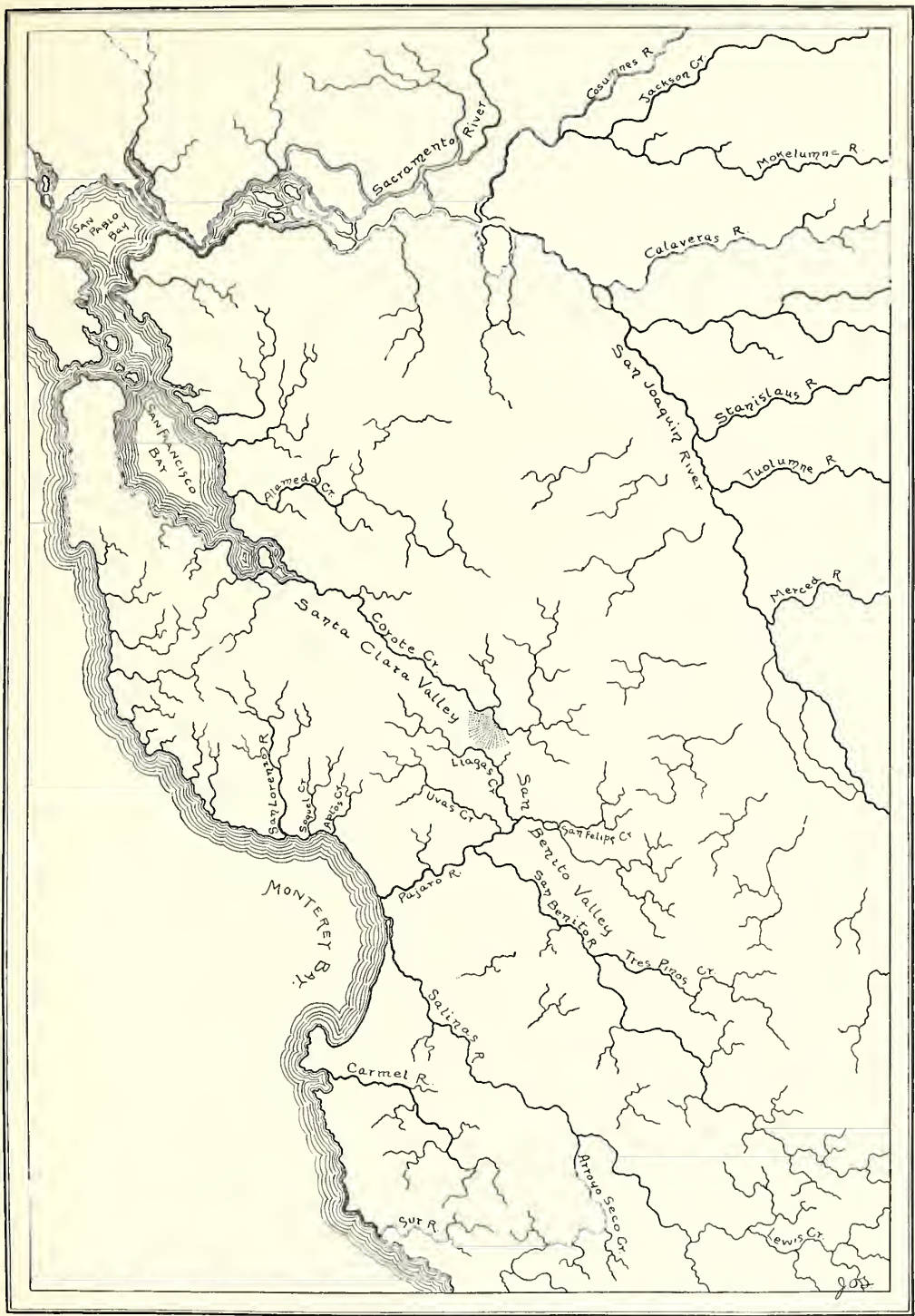
Cottus aleuticus Gilbert. *Aleutian bullhead.*

Cottus aleuticus appears to be associated with *C. asper*, often being taken in the same seine haul with the latter.

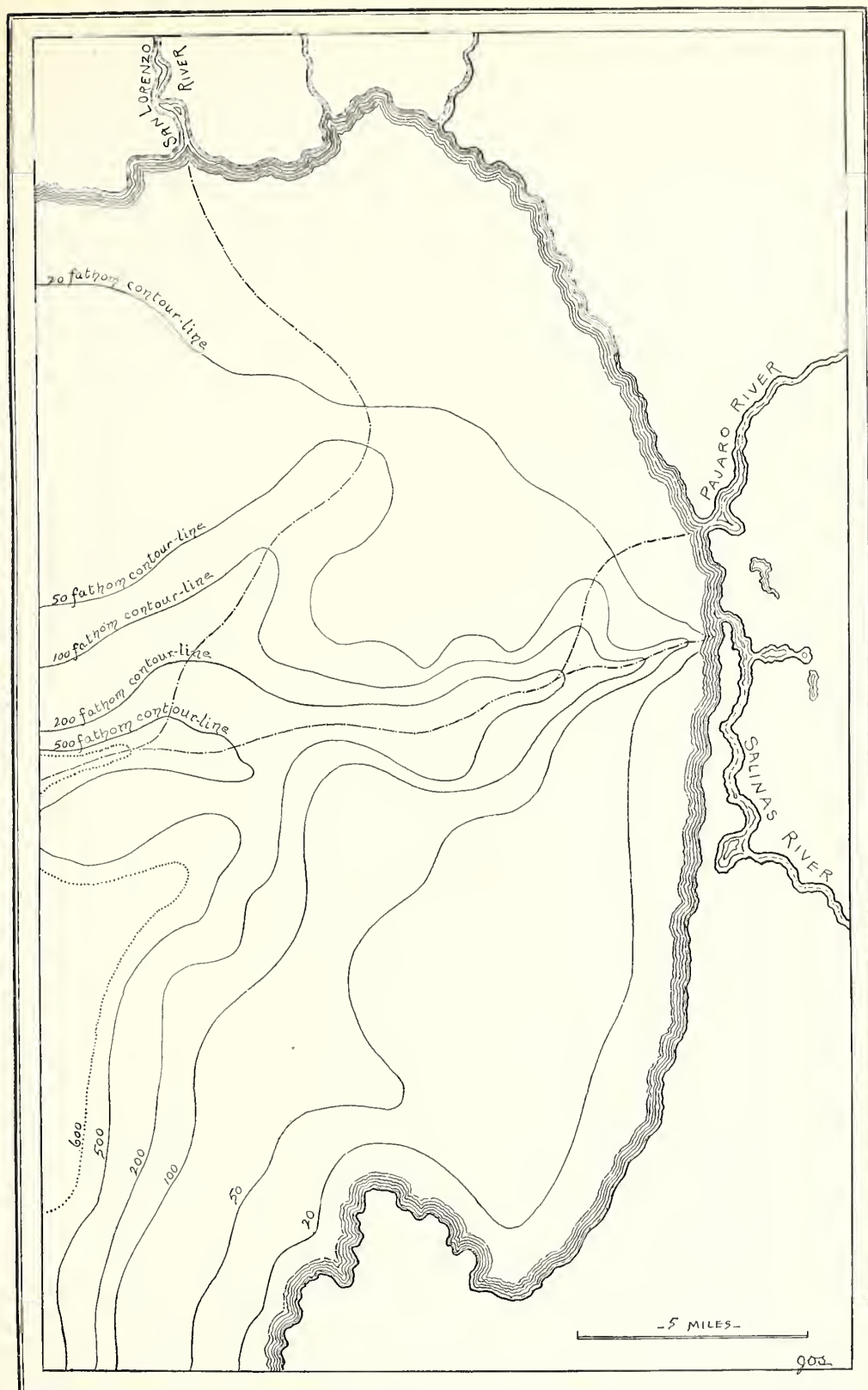
Cottus gulosus (Girard). *Rifflefish.*

Cottus gulosus inhabits the upper courses of the creeks, apparently preferring the clear, cool water of the ripples, where specimens may often be seen lying on the bottom near large pebbles or boulders. They approach food with short, jerky movements, always keeping close to the bottom. They are difficult to collect, as they usually dart under the lead line of the net if it passes over the least obstruction.

Spines or rays.....	Dorsal spines.			Dorsal rays.			Anal rays.			Pectoral rays.		
	7	8	9	17	18	19	13	14	15	14	15	16
Uvas Creek.....	2	9	.....	1	9	1	.....	9	2	1	10	.....
Llagas Creek.....	2	16	2	2	12	6	1	16	3	1	18	1



Map of the Pajaro River system and contiguous basins.



Topographic map of Monterey Bay, showing submerged valley and probable ancient courses of Pajaro, San Lorenzo, and Salinas Rivers.



1



2



3



4



5



6



7



8

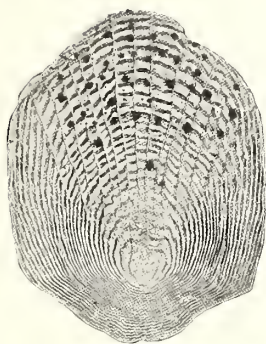
FIG. 1 TO 4.—Scales of *Hesperoleucus symmetricus*, $\times 20$; San Joaquin River at Polaski, Oct. 20; length, 90 to 108 millimeters.
 FIG. 5 TO 8.—Scales of *Hesperoleucus venustus*, $\times 20$; (5 and 6) Coyote Creek, July 25, length 85 millimeters; (7) Alameda Creek, June 16, length 94 millimeters; (8) Napa River, May 26, length 94 millimeters.



9



10



11



12



13

FIG. 9 AND 10.—Scales of *Hesperoleucus venustus*, $\times 20$; (9) Conn Creek, May 26, length 104 millimeters; (10) Russian River, June 17, length 95 millimeters.

FIG. 11 TO 13.—Scales of *Hesperoleucus navarroensis*, $\times 20$; Navarro River, June 14; length 88 to 91 millimeters.



14



15



16



17



18



19



20

FIG. 14 TO 16.—Scales of *Hesperoleucus parvipinnis*, $\times 20$, Wheatfield Fork, Gualala River, June 6, length 74 to 79 millimeters.
FIG. 17 TO 20.—Scales of *Hesperoleucus mitrulus*, $\times 20$, Drew Creek, July 11, length 84 to 87 millimeters.

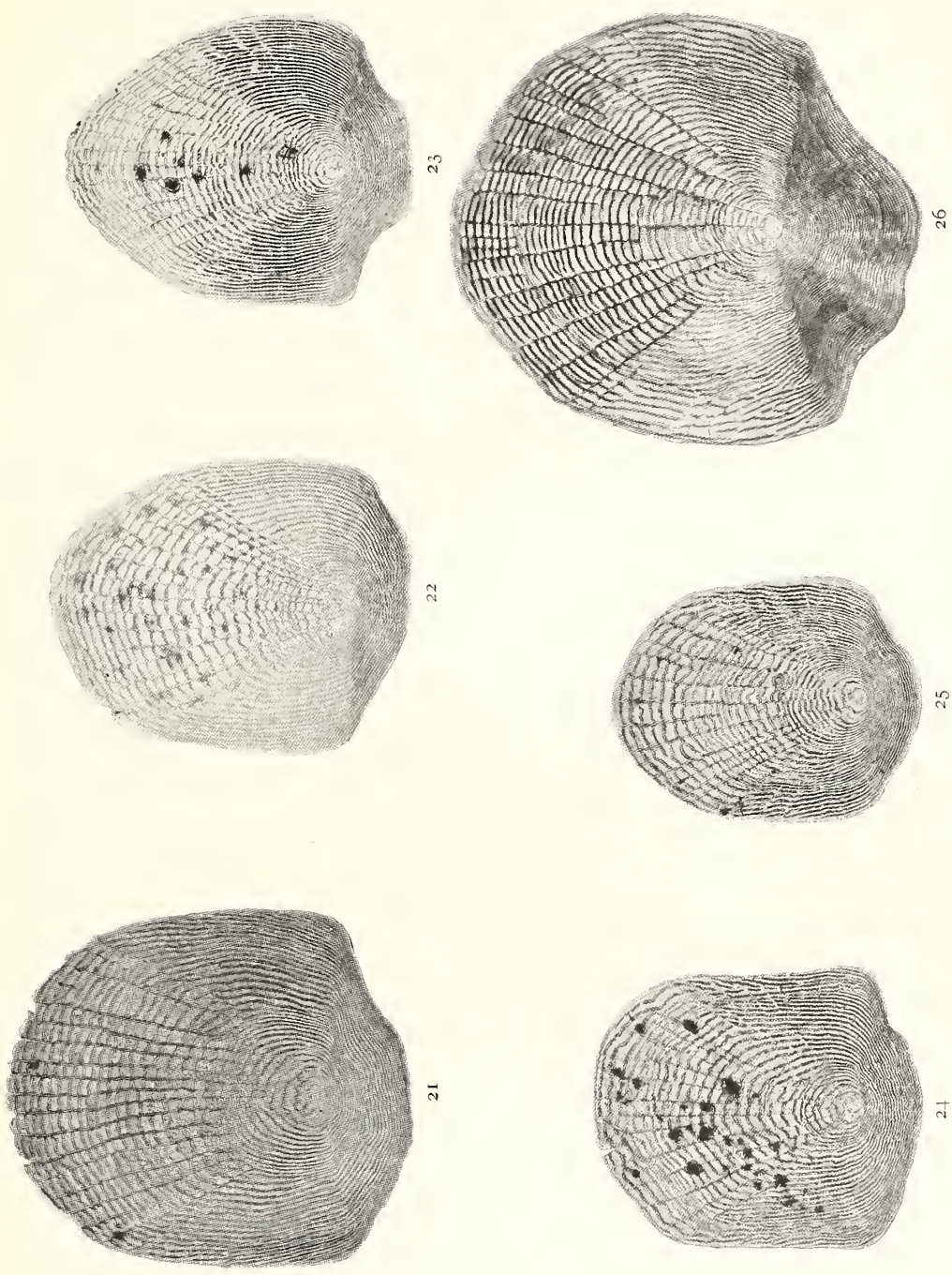


FIG. 21 TO 25.—Scales of *Hesperolencus subditus*, X 20.

FIG. 21.—Uvas Creek, Oct. 15, length 110 millimeters.
FIG. 22.—Uvas Creek, Oct. 15, length 85 millimeters.
FIG. 23.—Salinas River, Oct. 10, length 95 millimeters.
FIG. 24.—San Antonio Creek, July 24, length 89 millimeters.
FIG. 25.—Nacimiento Creek, July 16, length 85 millimeters.
FIG. 26.—Scale of *Lavinia ardesiaca*, X 17, Pajaro River, Aug. 4, length 195 millimeters.

ANATOMY AND HISTOLOGY OF THE ALIMENTARY
TRACT OF THE KING SALMON



By Charles W. Greene, Ph. D.
*Department of Physiology and Pharmacology,
University of Missouri*

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ANATOMY AND HISTOLOGY OF THE ALIMENTARY TRACT OF THE KING SALMON.



By CHARLES W. GREENE, Ph. D.,

Department of Physiology and Pharmacology, University of Missouri.



INTRODUCTORY.

In the older literature one finds discussions of the anatomy, histology, and embryology of a number of species of trout.^a More recently a brief histological study was made by Gulland on the Atlantic salmon, *Salmo salar*.^b This study of normal structures is very brief and is given by the author incidental to the presentation of certain degenerative changes in the digestive tract in the Scottish species. Gulland's paper covers only about six pages of printed matter, including both the normal and pathological findings. Previous to the work of Gulland, Miescher^c published certain gross findings in the Rhine representative of the Atlantic salmon, but he does not offer histological details.

No studies presenting the details of the anatomy and histology of the alimentary tract of the king salmon thus far have been published. In my studies on the function of the digestive tract of this salmon, and in similar studies of the changes that occur during the spawning migration of the species, it was found necessary to examine the normal structural characteristics of this interesting fish. The facts determined in these studies are set forth in the present paper.

The digestive tract of the king salmon is, on the whole, quite similar in its gross anatomy to that of the Atlantic salmon, *Salmo salar*, and also is comparable to the anatomy of the species of trout. The alimentary canal of the king salmon has the relatively simple structure which characterizes carnivorous fishes in general. It consists of the usual parts, i. e., the mouth, esophagus, stomach, and intestine. Of special interest are the numerous diverticula of the small intestine attached to that limb of the intestine which immediately follows the stomach, and known as the pyloric cæca. Figure 3 presents a salmon in outline in which the anatomy of the alimentary tract is shown in its normal relations.

The anatomy of the mouth is not presented in this paper.

^a Oppel, Albert: *Mikroskopische Anatomie*, hd. 1, p. 28, 70, etc., hd. 2, p. 7, etc.

^b Paton, D. Noël: *Life history of the salmon*. Article 3, by Gulland, "Minute structure of the digestive tract of the salmon, and the changes which occur in it in fresh water." Report of the Fisheries Board for Scotland, 1898, p. 13.

^c Miescher, Friedrich: *Statistische und Biologische Beiträge zur Kenntniss vom Leben des Rheinlachs im Süßwasser*. Schweizerischer Fischerei-Ausstellung zu Berlin, 1880, p. 154. Also reprinted in *Die Histochemischen und Physiologischen Arbeiten von Friedrich Miescher*, 1897, p. 116.

HISTOLOGY OF THE ESOPHAGUS.

The esophagus in the king salmon is a very short muscular tube extending from the posterior part of the pharyngeal cavity to the stomach. The length of the esophagus is only 3 to 5 centimeters, even in the largest salmon.

A cross section through the esophagus shows three coats, of which the thickest and most important is the muscular coat. The lining of the esophageal tube is composed of epithelium which is complexly folded and which rests upon a subepithelial connective tissue foundation.

EPITHELIAL COAT OF THE ESOPHAGUS.

The epithelial coat of the salmon esophagus consists of columnar epithelial cells. In the anterior portion this epithelial layer is supported by one or two irregular layers of deeper cells. This region represents the transitional stages between the stratified epithelium of the mouth and pharynx and the single layer of epithelial cells lining the rest of the alimentary tract. The smaller basal epithelial cells are represented for some little distance down the esophagus, though they are relatively few in number except in the region just described.

Most of the epithelial cells have clear outer margins with a stainable protoplasm and the nucleus crowded to the base of the cell. This is interpreted as meaning that these cells are chiefly concerned with the production of mucus, that they are in fact mucous cells.

The mucous coat is complexly folded. In microscopic cross section the folds are often cut in such a way as to simulate simple tubular glands. When the gross folds are unusually large then these simple tubelike appearances may be located on the sides of the larger folds. This is a mechanical condition which appears later, i. e., especially in the mucous epithelium of the intestine, and in simpler form in the cæca. In all the sections available the esophagus is strongly contracted so that the epithelial coat is thrown into unusually rich folds. The study of cross sections leads one to the view that if the esophagus were fully distended most of these epithelial folds would be eliminated. No differentiation among the epithelial cells of the esophageal mucosa could be discovered.

SUBEPITHELIAL CONNECTIVE TISSUE OR TUNICA PROPRIA.

This coat in the esophagus consists of a simple type of areolar connective tissue. The nuclei are small and oval, the connective tissue strands are open and especially loose in arrangement. Occasional blood vessels are noted in the sections. Just at the base of the epithelial coat the connective tissue is a trifle more dense and the fibers and nuclei are arranged parallel with the inner surface of the epithelial coat. No evidence of smooth muscle fibers or other specially differentiated cells was found in the tunica propria of the salmon esophagus.

MUSCULAR WALL OF THE ESOPHAGUS.

The muscular wall of the esophagus consists of a single circular coat. This is a thick, heavy muscular mass which is composed wholly of striated fibers. These fibers are about $15\ \mu$ in diameter. Their length was not determined, but they are relatively long. Numerous nuclei are found along every fiber, each nucleus lying just within the sarcolemma. The nuclei of the striated fibers are oval, but vary considerably in shape and size, averaging 6 by $9\ \mu$. The total thickness of the circular muscle coat amounts to about $200\ \mu$ in a young salmon 7 cm. long in which these measurements were made. In the adult fish of course the total mass of the muscle is very much greater.

SEROUS COAT.

The posterior end of the esophagus where it passes over into the stomach is free and therefore covered with a serous coat. The serous epithelial cells covering this coat are very thin, and are of the usual stratified type. No thick subserous connective tissue which characterizes the intestine and cæca was noted in the esophagus. It was noted, however, that numerous blood vessels are present just under the serous coat. This vascular factor characterizes the esophagus in all the salmon studied.

THE STOMACH.

FORM AND DIVISIONS OF THE STOMACH.

The stomach of the king salmon is a U-shaped organ. The first limb of the U extends from the esophagus straight posteriorly a distance equivalent to one-fourth the length of the fish. At this point the stomach makes a sharp bend and extends directly back toward the head for about one-third the length of the first division. In the adult the lengths of these divisions of the stomach vary in proportion to the total length of the fish, but in an average-sized salmon, 80 cm., the length of the first, or cardiac division is from 20 to 22 cm., and of the second or pyloric division, from 6 to 7 cm.

There is great variation in the size of the stomach in feeding salmon from Monterey Bay. In the market there are always individual fishes in which the stomachs are empty and contracted until the gastric cavity is obliterated, i. e., until the mucous folds are in contact and the cavity is a potential one only. In the empty condition the cardiac division of the stomach is a regular cylinder in form and shape. The contracted walls are firm and resistant to the touch, and the total diameter is reduced to 1.5 to 2 cm. The pyloric division is also contracted, is firm to the touch, and its diameter is a trifle less in any given salmon than that of the cardiac division. The mucosa is compressed into great longitudinal ridges or folds. When the stomach wall is split open for its full length and the cavity opened out, then these folds appear as prominent longitudinal ridges.

If only a small amount of food is present in the stomach—for example, a single small fish or a squid—the mucous lining is pressed firmly against this food mass and the gross shape of the stomach is much the same as in the empty organ. But in these instances

the mucous membrane is quite red in appearance, as though filled with an unusual supply of blood.

When a large mass of food is present in the stomach and that in an advanced stage of digestion, then the muscular walls are greatly relaxed, the stomach is more flaccid, and its diameter is enormously increased. The mucous coat is then quite free from folds and the whole wall is relatively thin and pliable. In this condition the capacity of the stomach is at its maximum. In another connection I have called attention to the finding of as many as 18 squid besides several small fishes in one such dilated stomach. In such an instance the diameter of the stomach is greatly increased, but the length remains quite constant.

COATS OF THE STOMACH WALL.

The anatomical divisions that constitute the stomach wall are essentially the same in the king salmon as for carnivorous fishes in general, the details of the structure of the salmon comparing very closely with the carnivorous type. Beginning with the lining mucous membrane, one may record in their regular order the following coats:

- I. Mucosa.
 - 1. Epithelium.
 - 2. Tunica propria.
 - 3. Stratum compactum.
 - 4. Stratum granulosum.
 - 5. Muscularis mucosa.
- II. Submucosa.
- III. Muscularis.
 - 1. Muscularis circularis.
 - 2. Muscularis longitudinalis.
- IV. Serosa.

The stomach of the king salmon is characterized by the extensive differentiations of the mucosa, which possesses the five coats as outlined above. The structure is noteworthy for three features—first, the great differentiation of the gastric glands in the cardiac region; second, the strong development of the stratum compactum in this species; and, third, for the presence of a constant and definite layer of cells of special structure to be described more fully later as the stratum granulosum. This type of granule cell is present constantly, not only in the stomach but in all divisions of the alimentary canal. Its size and evident importance in the salmon physiology amply justify its description as a definite coat.

HISTOLOGY OF THE GASTRIC MUCOSA.

The epithelial coat of the salmon stomach presents a rather thick layer. A section through this coat will vary according to the location of the area in the stomach from which it is taken. In the cardiac region the coat is thickest, the thickness being due to the presence of the gastric glands. In the pyloric division of the stomach the structure is simpler, as will be described later.

Epithelium of the cardiac stomach.—The cardiac epithelial coat presents on the surface always a layer of slender cylindrical cells of the usual cylindrical or columnar epithelial type. Perhaps these cells are more slender than is noted in many animal species. Where the coat forms sharp folds the cylindrical cells will in cross section of the folds present great fan-shaped masses.

The cells are almost always slender at the base and somewhat broader at the apex of the cell. They vary in size, but average in thickness $3\ \mu$ at the base and $6\ \mu$ at the free end. The length of the cells of the free surface varies from 33 to 50 μ . The nucleus is in the basal third of the cell. It is a slender oval mass showing a rather close chromatin network. The normal size of the nucleus is on an average 2 by 6 μ . The outer fourth of the superficial epithelial cell is usually paler, contains less stainable protoplasm, and is relatively larger. This zone is one that takes a most active part in fat absorption. The cylindrical cells are not granular. Gulland's^a figure 8 represents a view of the cells for *Salmo salar*. The whole gastric epithelium is thrown into deep folds in the empty stomach, folds which are more or less obliterated in the actively digesting organ. When the walls are not greatly distended then the folds are deeper and more pronounced, and the superficial epithelial coat and the deeper seated gastric glands are rather distorted in position and appearance. A more normal relation of the parts of the mucosa is presented in the distended stomach, and in such a stomach, moreover, the relations are most readily determined. The most superficial of the cylindrical cells, the ones that form the free surface bordering on the lumen of the stomach, are the longest and most slender. From this surface, extending down into and lining the mouths of the crypts, the cylindrical cells become gradually and uninterruptedly smaller. The only change in type, however, is one of relative size of the cells. The crypts themselves vary greatly in depth, forming longer or shorter tubes into the bottoms and sides of which the gastric glands open. (See fig. 3, pl. xxvi.)

The epithelial cells lining the tubes of the crypts nowhere present abrupt change in structure from the most superficial type. Where the tubes are relatively long the lining cells, presumably the neck cells of Gulland, become short, cubical, and of uniform size. In the bottoms of the crypts the cubical type of cylindrical cell changes quite suddenly to the secreting type. There is no intermediate structurally different type of neck cell in the king salmon as suggested by Gulland^a for the Atlantic salmon. The term, "neck cell," when it is used, must refer merely to the fore-shortened type of cylindrical cell.

The point at which the transition takes place from the cylindrical to the glandular type is rather difficult to observe, since it seldom happens that a vertical section cuts through this critical region. Gulland presents a figure of such a transitional region for the Atlantic salmon and calls attention to the change in cell type. In figure 3, plate xxvi, I show the relation as it exists in the adult king salmon. The opening between the crypt and the gland duet is distinctly constricted and rarely cut exactly through its lumen, except in stomachs taken at a stage of digestion in which the whole wall is decidedly relaxed. Then the gland mouth may be more distended or relaxed.

^a Paton, D. Noël, op. cit., p. 5, and fig. 9.

The superficial epithelial cells undoubtedly serve for the function of absorption throughout the full extent of their surface, even down into the depths of the crypts. This is proven in at least one instance, i. e., for the fats, as detailed in a later report of this series. Fat in process of absorption was found in the cylindrical cells down in the bottoms of the crypts, as well as in those cells on the free surface of the gastric epithelial coat.

The epithelial coat of the cardiac stomach is very thick because of the presence of the numerous gastric glands. The gastric glands are of the tubular type, though they are very irregular as to their position, size, and general arrangement. The glands are diverticula of the superficial crypts described above. Each crypt receives the openings from a number of the gastric glands. The openings are as a rule more numerous and more prominent over the bottoms of the crypts, but many glands open into the sides of and about the rims of the crypts. At the bottom of the average crypt there is a cluster of from three to six glands, the mouths of which open together or sometimes separately into the crypt. In the deeper lying crypts glands are more often to be found opening into the side of a crypt near its middle, or even near its superficial portion, than in those crypts located over the surface of a gross mucous ridge. These latter glands are very short and compact, and they are very irregular in shape and often oval in cross section.

The size of the gastric glands varies greatly, depending on their exact position. The more superficial glands are smaller and the deep ones larger and longer. The variation is due not so much to the size of the gland cells as to the number in the tube, yet there is greater variation in the size of the cells than noted for higher vertebrates.

The gland tubes are not always linear, on the contrary they are bent and very irregular in their extent. In the younger salmon the glands are more tubular as a rule, but older examples are often noted in which the tubes are bilobed at the blind end, or have one or more diverticula in the side walls. A cross section of such a mass of tubes presents very diverse and irregular outlines.

The gland cells are of a single type and are irregularly polygonal in shape, similar to the chief cells in the peptic glands of higher vertebrates. The cells are somewhat larger in the salmon, averaging 12 to 20 μ long by 9 to 18 μ in greatest width. In a cross section of a tube the cells do not approximate each other so closely as in the higher vertebrates, thus forming a wider lumen. (See fig. 4, pl. xxvi.)

The nuclei of the gastric secreting cells are slightly oval, almost spherical and rather large, with a nuclear diameter of from 5 to 6 μ . They are located near the bases of the cells. The cytoplasm of the gastric gland cells is highly granular, being filled with doubly refractive rather small zymogen granules. Special study has not been made of the chemical character of these granules. It has been noted, however, that the granules are relatively very small and that they stain in the characteristic way with eosin and with iron hæmatoxylin. The zymogen granules take these stains lightly and the technique must be followed with considerable care. The granules vary in numbers in the glands of different fishes from the feeding grounds, presumably, as Gulland suggests for *Salmo salar*, in relation to the stage of the progress of secretion and digestion. In certain

young salmon ^a taken early in the progress of an active stage of digestion these gland cells are charged with granules throughout their entire cytoplasm. The granules are smaller and less refractive than the granules of the "granule cells" described below.

The vascular supply of the mucosa of the cardiac division of the stomach has not been especially studied by the methods of injection. Enough has been learned, however, from the study of histological preparations to determine that there is a comparatively rich blood supply to the gastric mucous membrane. Small blood vessels are found in the tunica propria just at the bases of the gastric-gland cells, also between the glands themselves. Numerous capillaries are found about the bases of the glands and in the connective tissue supporting the superficial epithelium in the regions lying just under the superficial epithelium and between the crypts, where there is a relatively high content of supporting connective tissue. Numerous capillary nets are noted. Ofttimes in relatively thick sections capillary nets are noted which resemble somewhat the arrangement of smaller blood vessels as demonstrated by Mall.

Epithelium of the pyloric stomach.—In the pyloric division of the stomach the mucosa forms deep folds arranged in a general longitudinal direction. These folds are covered throughout with the cylindrical type of epithelial cell. Those portions of the cells of the folds bordering on the cavity of the stomach are only slightly different from the cells in the deeper grooves between the folds. This difference consists largely in the fact that the surface cells are more slender and somewhat more club-shaped, comparable to the superficial cells in the cardiac region of the stomach. There are no proper gastric glands in this division of the stomach. The pyloric epithelium forms counterfolds with a number of shallow epithelial pits in the first two-thirds of this division of the stomach. These shallow pits in the mucous epithelium are present occasionally on the sides of the walls of the larger longitudinal folds mentioned above. The many apparent pyloric glands, as seen in the transverse sections of the pyloric gastric mucosa, are in reality only transverse sections of the longitudinal folds. Near the pyloric valve, marking the boundary between the stomach and the intestine, the gastric mucosa consists of a series of simple longitudinal folds, and no suggestion of pyloric gland-like pits occurs. The longitudinal folds are permanent ones, a fact indicated by the somewhat longer and more slender cells present on the free borders of the folds. (See fig. 3, pl. xxvi.) This type of structure extends to the circular constriction, the pyloric valve, marking the boundary between the pyloric stomach and the pyloric intestine.^b

Tunica propria.—The connective tissue of the stomach mucosa, on which the epithelial coat rests, is called the tunica propria. The term is here used to designate all that structure between the basement membrane of the epithelium and the stratum compactum. The tissue forms an open network varying in general outlines and in thickness according to the degree of stretching of the stomach walls. Folds of the tunica extend up into the grooves among the gastric glands, forming a supporting net-

^a Salmon no. 45 and 46, Pacific Grove, July 10 and 11, 1911. These are the salmon that were artificially fed as described in later paper (now in manuscript).

^b A view of the pyloric valve is given in a figure in the report dealing with the gross anatomical relations in the salmon. This transverse section is through the body at a plane just anterior to the pyloric valve.

work. This network in certain regions forms strong strands quite to the bases of the superficial epithelial cells. The connective tissue is of the compact areolar type, the fibers of which run in a general way parallel with the stratum compactum beneath. This tissue forms a proper support not only for the epithelial coat, including its glands, but also for its blood vessels and nerves. Numerous small arteries and veins are present in the thicker portion of the tunica, and branches from these form a capillary network in the meshes among the glands, as previously stated. The type of connective tissue cell present here calls for no particular comment, yet there are a number of cells of the type described below as granule cells present just within the stratum compactum. In the normal tissue of the tunica these granule cells are not numerous, though in the degenerated tissue, as will be described in a later report, they become more numerous in this region.

Stratum compactum.—A structure of peculiar type and significance because of the fact that it is not uniformly present in the walls of the alimentary canals of vertebrates is the stratum compactum of Oppel. In the salmon stomach this tissue forms a well-developed sheath. It is not in so compact a mass as in the intestine and in the cæca described below. Gulland ^a says of *Salmo salar*, "This layer in whatever plane the stomach is cut is always found as a compact hyaline band lying rather nearer the muscularis mucosæ than it does to the fundi of the glands. It is, of course, pierced by blood vessels, etc., but I have never seen muscle strands from the muscularis mucosæ passing through it. It contains no nuclei, and no structure can be made out in it by ordinary methods. Nuclei lie upon it, however, and the fibers of the connective tissue on either side are directly continuous with it (fig. 10)." This characterization of the *Salmo salar* stratum compactum applies very well to the stratum of the king salmon. In the king salmon there is the one thick sheath, very heavy and well marked and of wavy outline. This thicker sheath lies toward the inner or epithelial side of the gastric wall. However, in transverse sections it is always noted that the main portion of the stratum bears a network of strands and fibers of the characteristic staining reactions located both on its inner and outer surfaces. The network on the outer surface is of heavier strands and is about twice as extensive as that on the inner surface. This network of fibers runs in a general circular direction.

The substance of the stratum compactum takes a Mallory connective tissue stain. It is shown by this stain to be a homogeneous, compact, nonfibrous mass, evidently of collagenous material. Iron hæmatoxylin stain also fails to reveal fibrous structure. Lying on the surface of the strands one notes here and there connective tissue corpuscles. The surface is sharply marked by a substance or structure which takes certain stains somewhat more sharply than the central portion of the stratum. Occasional nuclei are embedded in this superficial layer.

In the open meshes of the stratum there are always found a number of cells of the type designated in this paper as granule cells. These cells form a part of a special coat, the stratum granulosum. (See fig. 3, pl. xxvi.)

^a Paton, D. Noël, op. cit., p. 14.

Stratum granulosum.—There is present throughout the alimentary tract of the king salmon a special type of cell forming a distinct layer or coat. Throughout the preliminary studies this layer has been designated the granule cell layer, on account of the distinctive characteristic of the cells composing it. Oppel has described a stratum granulosum for the mucosa of certain animals, and while the homologies are not certain in the king salmon, I propose to use this designation as a permanent name for the structure in question present in *Oncorhynchus*.

The granule cell layer is a part of the mucosa. In the salmon stomach its cells lie between the stratum compactum and the muscularis mucosæ and in the meshes of the stratum compactum itself. The granule cells form quite a dense and well-marked coat, not only in the stomach but in the intestine and cæca. However, the boundaries of this coat are not sharp on either the inner or outer margin. On the inner margin cells of the coat are found scattered among the inner meshes of the network of the stratum compactum and occasionally in the tunica propria. The outer margin or boundary of the zone is sharper. The inner margin of the muscularis mucosæ marks this boundary. Yet a few scattered granule cells are found in the connective tissue of the submucosa outside the muscularis proper.

The arrangement of the cells about the surface of the layer, also the occasional displaced granule cells, suggest that these cells may be amœboid and migratory. This I believe to be true to a very limited extent. But I have not yet succeeded in observing amœboid activity in teased living cells. In fasting salmon, however, I find extensive migration of the cells into the tunica propria on the inner border and into the muscular coats on the outer border of the stratum granulosum. This observation is especially striking in the degenerating cæca. The granule cells, however, are never found far removed from the proper location of the stratum. They have not been observed in the blood vessels, in the liver, or in any skeletal muscle tissue.

The granule cells are supported by a delicate meshwork of fibrils of the histological type and staining properties of the stratum compactum. There is no distinct pattern or type of arrangement of the cells. That portion of the layer just within the muscularis is from four to eight cells thick. Many blood vessels pierce this coat on the way to the deeper structures. But ordinary histological methods do not reveal any definite vascular supply to this structure. It seems to derive its nutritive materials from the capillaries of the adjacent muscles and of the tunica propria.

The granule cells are irregularly oval in outline, varying in size between 6 by 9 μ and 7 by 12 μ in diameter. The nucleus is always eccentric in position and relatively small in size, 2.5 by 4 μ in diameter.

The special and characteristic feature of the structure of these cells is the presence of the cytoplasmic granules that always crowd them, uniformly filling the cell body. The only differentiation noted in this regard is that those cells most free and isolated from the stratum proper have somewhat fewer granules.

The granules stain deeply with a number of dyes, such as eosin, orange G, acid fuchsin, etc. The sharpest differentiation is obtained by staining with iron hæmatoxylin,

preferably after Bensley's corrosive bichromate fixative. The iron hæmatoxylin, differentiated to just the right degree, stains the granules an intense bluish black, while the rest of the cytoplasm is clear or may be counterstained with eosin. The cell granules are relatively uniform in diameter. In many preparations one can distinguish only a slight variation in the size of the granules. In certain preparations, however, there is considerable variation in the diameters of the granules within a single cell, a variation that is uniform throughout the cells of a given stomach. The size of the granules in a series of specimens measured varied around 0.8 to 1 μ in diameter. The extremes noted in these preparations were 0.4 and 1.2 μ , respectively. In several samples where the granules were especially uniform in diameter and in which the granules crowded the cell cytoplasm for its full extent the size ran from 0.4 to 0.5 μ in diameter.

The salmon pancreatic cells and the gastric gland cells also contain granules, zymogen granules. But the number and arrangement of granules in each of these two types of cells is characteristically different from that of the granule cells proper. Measurements show that the zymogen granules of the pancreatic cells also vary through a rather wide range. In sections from the same salmon from which the measurements of granule cells given above were taken the pancreatic zymogen granules measure from 0.6 to 1.5 μ in diameter. The number of granules in the individual cells was small and the granules were located chiefly on one side of the cell, presumably the side next the lumen. In another fish the granules of the cells of the pancreas measured from 0.4 to 1 μ in diameter. The loading of granules was somewhat greater in number than in the cells with the larger granules.

The granules of the granule cells take stains somewhat differently from the granules of either of the two types of secreting cells under comparison. The pancreatic cells and the granule cells of the pyloric cæca present in the same microscopic field are always in sharp contrast. The stain of the granules of the granule cells is sharper, more distinct and brilliant, and of a different shade of color when both are stained with the same dye.

Evidence of solution of the granules of these peculiar cells has been observed in the preparation of tissues by certain fixatives. Unfortunately this factor has not been investigated sufficiently for final report.

The character of the distribution of the cells, the staining properties of the granules, and the persistence of these cells during marked degenerative changes of much of the structure of the stomach and other portions of the alimentary canal all point to some function of special nature. This function, I believe, is that of internal secretion. The granules present are, therefore, true zymogen granules. In another connection I have presented the view that this function is one of lipase production. The absence of any tubular arrangement or ducts, and the apparent lack of an adequate capillary net would suggest that the granule cells must discharge their products directly into the surrounding tissue spaces from which distribution takes place.

The granule cells were observed by Gulland.^a He figures a bit of the stratum compactum and adherent granule cells in its meshes. Gulland calls these cells "large

^a Paton, D. No. 1, op. cit., pl. 4, fig. 10.

eosinophile leucocytes." This identification will not apply to the cells of the king salmon for the following reasons: First, the salmon leucocytes are very much smaller than the cells in question. Also one never finds a cell of the granule-cell type inside a blood vessel, though diligent search has been made. Second, the granule cells form a distinct and persistent structure in a definite region of the stomach and alimentary tract. It is out of the question that the eosinophiles of the blood should form such a cell grouping in every animal of whatever age.

Muscularis mucosæ.—The muscularis mucosæ is present in the salmon stomach. It consists of a rather thick double layer of muscle fibers, relatively much thicker than the corresponding coat in the mammalia. The fibers run both in the circular and in the longitudinal direction. There is much irregularity in the direction of the fibers, due in part to the fact that the muscularis mucosæ follows the folds of the mucosa rather than the outlines of the outer and heavier coats of the stomach. There are many free bundles of fibers more or less irregularly disposed in the folds of the submucosa and on the external or outer surface of the muscularis.

In the contracted stomach, in which the mucosa is thrown into deep longitudinal ridges, a cross section shows that the muscularis mucosa takes a somewhat sinuous or wavy course in its position between the mucous epithelium and the outer muscular coats. In places the muscularis will be in contact with the inner or circular muscle coat, where its thickness is shown to be from 40 to 60 per cent as great as that of the muscularis circularis itself. In the loops of connective tissue between two such points of contact between the two muscular coats there are always found the free or isolated bundles of muscles mentioned above. These isolated bundles unquestionably belong to the muscularis mucosæ.

HISTOLOGY OF THE GASTRIC SUBMUCOSA.

The submucosa of the king salmon forms an irregular connective tissue coat between the muscularis mucosæ and the muscularis circularis. In places the submucosa seems quite obliterated and the two muscular coats are in contact. Under the deeper longitudinal folds of the mucosa the submucosa forms quite extensive masses of loose areolar connective tissue. Evidently in the salmon stomach this layer forms an adaptable coat for allowing the mucosa to slide over the inner surface of the muscularis circularis or vice versa.

The submucosa contains in its meshes numerous blood vessels of different sizes. There are also isolated bundles of muscle fibers from the muscularis mucosæ, and a sprinkling of granule cells that have wandered from the stratum granulosum.

HISTOLOGY OF THE GASTRIC MUSCLE COATS.

The proper muscle coats of the salmon stomach are two in number, the circularis and the longitudinalis. Between the two, and rather more deeply embedded in the longitudinalis, is the plexus of Auerbach, which should be mentioned in this connection.

Muscularis circularis.—The inner of the two muscle coats is the circular layer. It is a well-developed sheet of muscle in the salmon stomach, as shown in every cross

section of the gastric walls. It is about twice the thickness of the longitudinal muscle sheet.

The circular muscle is composed of smooth muscle fibers in the pyloric and lower three-fourths of the cardiac division of the stomach. Striated muscle cells extend down from the esophagus for some little distance, about one-fourth the length of the cardiac end. The point has been determined only in the young, where the striated fibers extend well below the esophageal boundary of the gastric gland region. There is no special peculiarity of structure of the gastric smooth muscle fibers. A rich vascular supply permeates this muscle coat, the blood vessels being for the most part small branches of the vessels lying between the two muscle coats.

Muscularis longitudinalis.—This is the outer of the two muscle coats of the stomach. It is well separated from the circularis by the numerous blood vessels and bundles of nerves of the Auerbach plexus, together with the connective tissue supporting these structures. These smooth fibers are rather less compact in arrangement than the circularis, perhaps due to the numerous blood vessels that are found in its substance. This coat is of course pierced by every vessel penetrating to the deeper structures. The striated muscle fibers of the upper end of the stomach are not found in the longitudinal muscle. This coat is very thin over the esophageal end of the stomach.

Plexus of Auerbach.—This nerve complex has not been sufficiently studied. It may be noted here, however, that the plexus is strongly developed in the king salmon stomach and in the other parts of the alimentary canal. Relatively large bundles of fibers are to be found between the two muscle coats and embedded in the longitudinal coat.

HISTOLOGY OF THE GASTRIC SEROSA.

The serosa of the salmon is formed by the single layer of plate-like epithelioid cells that is found in all the vertebrates of the higher series. Under certain conditions these cells become much thicker, i. e., quite cubical in shape. This form has been especially noted in the retrogressive changes that occur during the migration fast of the king salmon.

THE INTESTINE.

FORM AND DIVISIONS OF THE INTESTINE.

The intestinal portion of the alimentary tract of the salmon is, like the stomach, a U-shaped tube. In this case the first limb of the U is relatively short. It includes that portion of the intestine which has the numerous diverticula, the pyloric cæca. This limb begins at the pyloric valve which marks the limit of the pyloric end of the stomach. It extends anteriorly to about the level of the point where the esophagus and stomach join. At this level there is a sweeping bend in the intestine from the ventral to the dorsal position in the celomic cavity. The intestine here takes a position along the dorsal lateral side of the stomach and runs a straight posterior course to the cloaca and vent. This straight stretch of the intestine forms the second limb of the U, and is considerably longer than the first limb. In the adult salmon the two divisions of the intestine vary in length in proportion to the length of the fish. But for an 80-cm.

salmon the average length for the first limb is from 9 to 10 cm., that of the second limb from 28 to 30 cm. The last 4 or 5 centimeters of the intestine form a somewhat prominent enlargement, the cloaca.

There is a considerable variation in the size of the intestinal tube, even in fishes of the same length. This variation is greatest in the pyloric portion where the numerous cæca are attached. The variation in size is, however, dependent upon the degree of distension by food materials. It is largely an adaptation of the tube to its content, in so far as the diameter is concerned. If the tube be widely dilated the structural walls are correspondingly thin.

APPENDAGES OF THE INTESTINE.

Along the full length of the pyloric intestine there are numerous diverticula, the pyloric cæca. There is considerable variation in the number of cæca in different individuals of the genus *Oncorhynchus*. Jordan and Evermann, in "Fishes of North and Middle America," state that the number of cæca in the king salmon varies from 140 to 185. The larger number would seem to be more nearly the average.

The cæca are absent from the line of the wall of the pyloric intestine represented by the inner curvature. This line is marked by the attachment of intestinal blood vessels and of the gall and pancreatic ducts. All other portions of the wall of this limb of the intestine are studded thickly with pyloric cæca. The cæca, as a rule, arise as individual diverticula coming off at right angles to the surface and then bending posteriorly to lie like a fringe about the end of the pyloric stomach, and overlapping each other from this point for the full extent of the pyloric intestine. (See fig. 1.) The diameter of a cæcum at the base is usually somewhat less than in the main body of the diverticulum, averaging from 5 to 6 mm. Just outside the bases the cæca are somewhat larger—from 7 to 8 mm. in diameter. From this point to their tips they taper very gently to terminate in a blind sac.

The lengths of the cæca vary greatly in different regions of the pyloric intestine. The longest cæca are found at the origin of the intestine and just within the pyloric valve. At this point the appendages reach a length of from 6 to 8 cm., even longer in larger fishes. In any given segment those cæca that border on the line of the inner curvature are apt to be slightly shorter than the others in this segment. The lengths diminish progressively from the pyloric valve to the most anterior portion of the pyloric intestine. The last cæca are found on the ventral surface of the dorsal portion of the pyloric intestine, just where the anterior bend ceases and the straight limb of the intestine begins. These cæca are often 1 cm. or less in length, and the last two or three usually stand in a single row along the extent of the intestinal tube.

The pyloric cæca in their number, size, and arrangement form one of the most striking characteristics of the intestinal tract of this entire genus. In fact, the number is sufficiently constant to be given by systematists as a specific character. In the past the physiological function of these organs has been somewhat in doubt, but in the course of this work we have, fortunately, been able experimentally to establish certain points in their physiological economy to the salmon.

INTESTINAL COATS.

The coats of the intestinal tube are not so numerous as in the stomach. Certain parts present in the latter organ are not present in the intestinal tract, either in the intestine proper or in the pyloric cæca. Those structural coats that are present in the intestine are the following, beginning with the mucous membrane:

I. Mucosa.

1. Epithelial coat.
2. Tunica propria.
3. Stratum compactum.
4. Stratum granulosum.

II. Muscularis.

1. Muscularis circularis.
2. Muscularis longitudinalis.

III. Serosa.

HISTOLOGY OF THE MUCOSA.

Epithelial coat.—The epithelial coat of the intestinal mucosa is very simple as to structure, but rather complex as to its folding. A section at right angles through this coat will always show a single layer of columnar epithelial cells. I have been unable to show any differentiation in the structure of these cells in the different regions of the coat. The foldings of the mucous epithelium, however, are so complicated that it is difficult to secure right-angled sections through any great extent in any single section. In a cross section of the middle portion of the intestine which is uncomplicated by the origin of pyloric cæca, it will be noted that the mucosa is thrown into relatively complex longitudinal folds (figure 5). Occasionally in a widely distended intestine these folds are somewhat smoothed out, so that the arrangement seems less complex. If, however, the intestine be sharply contracted, then there are not only general longitudinal folds but many smaller collateral folds. Edinger^a in one of his plates presents a series of figures to show the character of the folding of the mucosa in fishes. The type of folding that he figures holds for the intestine of the salmon. In another place^b I have given a brief description of this folding as it appears in the pyloric cæca. There, however, the mucosa is more simple in its arrangement than in the intestine.

In a transverse section through a longitudinal fold in the intestinal mucosa the fold or ridge itself will have secondary pits or grooves on its lateral extent. Very often it happens that the section will present the appearance of definite tubes, or be through what looks like simple tubular glands, or sections of wide oval loops of epithelium will be shown. The tubelike structures do, indeed, suggest definite intestinal glands in the mucosa, but there is absolutely no histological differentiation between the cells of these narrow pitlike folds and the cells of the free epithelial surface. Although the folding of the epithelium is rather complicated one must accept the fact that the complexity of folding is not accompanied by histological differentiation of structure.

^a Edinger, L.: Ueber die Schleimhaut des Fischdarmes, nebst Bemerkungen zur Phylogenese der Drüsen des Darmrohres. Archiv für mikroskopische Anatomie, bd. xiii, 1877, p. 651.

^b Greene, Chas. W.: "The absorption of fats by the alimentary tract with special reference to the function of the pyloric cæca in the king salmon, *Oncorhynchus tshawytscha*." Transactions of the American Fisheries Society, 1911, p. 261.

The mucous epithelium is constantly marked by the presence of two common types of cells in addition to the typical cylindrical epithelium; first, mucous cells, and second, wandering cells presumably of the leucocyte type. In a normal epithelium the number of mucous cells varies through wide extremes. In certain sections they are relatively rare, and there are long stretches of epithelium without a single goblet cell. In other material the number of mucous cells is relatively great, and certain studies made on fasting salmon strongly support the view that the number of goblet cells is greatly increased during the early fasting period when the mucous membrane as a whole is just beginning its retrogressive changes. Certainly the number of mucous cells is greater if the fasting be somewhat prolonged. The observations on the salmon support the current view that cylindrical epithelial cells may be transformed into goblet cells.

The wandering cells are indicated by the small round nuclei interstitially arranged with reference to the normal epithelial cells. The nuclei are found chiefly near the basal portion of the epithelial coat, but they may also be found between the outer limbs of the cylindrical cells. In the normal digesting fish taken from among those feeding naturally on the banks at Monterey there are comparatively few of the wandering cells. This observation is of special significance in connection with certain theories concerning the part these cells are assumed to take in the process of absorption. Certainly in the salmon the small number present is strongly against the theory that fat absorption is accomplished by the wandering leucocytes. Indeed no evidence supporting this view of their function has been found in connection with numerous fat-absorption experiments.

I have been unable to show any particular differentiation in different limbs of the intestine, in so far as the mucous epithelium is concerned. The only differences noted are limited to complexity of the folding. In the pyloric intestine where the spaces between the cæca are small and limited, the intestinal epithelium has very simple folds. In the middle of the straight limb of the intestine these folds are more complex.

Tunica propria.—The tunica propria of the salmon intestine is defined as the connective tissue support extending from the bases of the epithelial cells to the stratum compactum. The tissue is composed of white fibrous connective tissue of the areolar type, carrying cells and nuclei of the connective tissue varieties. It is a very thin layer except in those places where the mucosa is folded into deep ridges. In the latter case the tunica propria extends into these ridges, forming a connective tissue foundation for the support of the epithelial coat.

The strands of the tunica propria support the blood vessels lying under the epithelium. These blood vessels consist of relatively small arteries penetrating from the muscle coat and forming a rich capillary network under the epithelium proper.

Stratum compactum.—This peculiar structure which has been described in some detail for the stomach is also present throughout the intestine. It forms a thick, heavy sheath, lying midway between the epithelium and the circular muscle coat of the intestine. The stratum compactum is not so complex as in the stomach in that it has a thinner mass of strands over the surface of the main sheet. A transverse section of the intestinal wall will usually show a heavy wavy line of dense nonfibrous connective

tissue, which stains the characteristic blue with Mallory's connective tissue stain. Its composition in the intestine is apparently the same as in the stomach. The inner surface of this stratum, that is, the surface toward the middle of the lumen of the intestine, is marked by a few smaller strands of the same peculiar type of connective tissue. The outer surface of the stratum has two or three times as many of these smaller strands. A distinct network is formed by the strands extending over to the circular muscle coat. In the intestinal region the number and complexity of arrangement of the strands composing the stratum compactum is about 40 to 50 per cent as great as in the stomach.

Nowhere does there seem to be any direct opening or break through the thicker portion of the stratum compactum, except where blood vessels penetrate this coat, a point which Gulland has made in his study of the stratum compactum of the stomach of *Salmo salar*. It may very well be, as Oppel suggests, that the stratum compactum is a protective supporting membrane. It certainly acts as such for the stratum granulosum in *Oncorhynchus*, whether or not it forms a supporting structure for the whole intestine.

Stratum granulosum.—The meshes of the stratum compactum directly support a layer of the special type of cells which has been described in connection with the stomach as the granule cells. This layer, the stratum granulosum, is most dense in its arrangement in the outer network of the stratum compactum. There are a few cells more or less scattered, lying on the inner surface of the same connective tissue supporting membrane. The granule cells of the intestine are characterized by the same form and size and structural arrangements as described for the granule cells of the stomach. Here, also, they possess the uniformly distributed, highly refractive granules which take stains in the specific way already described.

These granule cells form a very definite and characteristic structure in the intestine and their appearance and presence indicate some function of a significance which one can not escape ascribing to the presence of the granules in the cells, a suggestion that has been briefly discussed in connection with the stomach.

There is no muscularis mucosæ present either in the intestine or in the pyloric appendages.

The submucous coat, which characterizes the structure of the walls of the stomach, is also absent in the intestine.

HISTOLOGY OF THE MUSCLE COATS.

The muscle coats of the salmon intestine consist of an inner circular and an outer longitudinal coat with the plexus of Auerbach and numerous blood vessels between.

Muscularis circularis.—The inner muscle coat of the intestine consists of fibers which run in a circular direction. It is a relatively well-developed muscle sheath about twice as thick as its fellow, the longitudinal muscle. It is composed wholly of smooth muscle fibers, the detailed structure of which does not vary in any particular way, so far as noted, from the usual type of smooth muscle. A rich vascular supply, consisting of smaller blood vessels and capillaries, is present in this coat, the capillaries coming quite largely from arterioles present between the two muscle coats.

Muscularis longitudinalis.—The outer intestinal muscle coat consists of longitudinal fibers. It is a rather thin coat composed of smooth fibers and carrying numerous small blood vessels within its mass or between it and the inner coat. The presence of the small blood vessels tends to break up to some extent the compactness of arrangement of the muscle fibers.

Plexus of Auerbach.—This nervous structure is quite prominent in all sections through the alimentary canal. It, however, has not yet been studied in detail for the salmon. The ganglia and the bundles of fibers of the plexus lie between the two muscle coats but rather largely imbedded in the inner wall of the outer coat.

HISTOLOGY OF THE SEROSA.

The serous coat of the salmon intestine is composed of a single layer of epithelial cells and the subserous supporting connective tissue. These cells are not so flat and attenuated as is usually the case for this coat in the intestines of mammals, but are more nearly cubical in shape, often quite cylindrical. Especially when the intestine is contracted are the cells of the serosa deeper than wide.

The subserous connective tissue is rather prominent in the salmon intestine. It consists of white fibrous connective tissue about twice as thick in total mass as the epithelial coat proper.

HISTOLOGY OF THE PYLORIC CAECA.

Oppel says, in volume II of *Mikroskopische Anatomie*, that "the pyloric caeca, when they exist, possess the structure of that portion of the alimentary tract on which they are attached." Gulland says of the caeca of the Scottish salmon that "in structure they exactly resemble the upper part of the intestine, so much so in fact that but for the difference in size it would be impossible to say whether a section came from one or the other." In the king salmon, too, the pyloric caeca are diverticula of the pyloric limb of the intestine, and one would naturally expect them to have a structure built on the same plan as the intestinal region from which they arise. This in general is true, though the pyloric portion of the intestine is so broken up by the origin of the numerous caeca that the intestinal structural constants are not altogether simple in this region.

The coats described above for the intestine are all present in the walls of the pyloric caeca. The only difference is one of relative complexity, or one might rather say simplicity, of arrangement. The parts enumerated from the lumen toward the outer wall are:

- I. Mucosa.
 - 1. Epithelium.
 - 2. Tunica propria.
 - 3. Stratum compactum.
 - 4. Stratum granulosum.
- II. Muscularis.
 - 1. Circularis.
 - 2. Longitudinalis.
- III. Serosa.
 - 1. Serosa proper.
 - 2. Subserosa.

MUCOSA.

Epithelial coat.—The epithelium of the pyloric cæca is a coat of one uniform type throughout, and consists of a single layer of slender cylindrical cells with interspersed goblet cells and wandering leucocytes. The epithelial coat reaches its greatest development in the normal adult animal, in which its total surface extent is eight times the outer surface of the cæcum. This relatively enormous extent is secured by deep folds of the coat, which extend out into the lumen of the appendage. Cross sections of the pyloric appendages show all possible varieties of section of the epithelium. There are transverse sections of simple tongue-like folds extending from near the stratum compactum to approximately the center of the lumen. These are not villi, though they appear so. On the other hand there are regions where the epithelium is cut obliquely, or even in a plane parallel with the surface of the epithelial coat for some extent. There is in such a picture necessarily a great amount of irregularity in the boundary outlines of the epithelial surface.

The picture just described is due to the fact that the epithelial coat of the mucosa is built on a simple but extremely flexible plan. There are no projections of its surface comparable to the villi of the small intestine in the mammalia, but there are many clefts and folds. If a king salmon's cæcum were completely relaxed as to its musculature and distended from the inside to its maximum extent, both as to length and as to circumference, its epithelial coat would be greatly smoothed out and comparatively simple. Its irregularities of surface still observable would be chiefly low longitudinal ridges broken here and there by transverse furrows and partial clefts. Relaxation of the muscular walls and dilation of the cæcum to this extent probably seldom occur in nature though oftentimes closely approximated. In a maximally stretched cæcum the proportion between the surface extent of the mucosa and the outer wall should be lower than the minimum given in the preceding paragraph. If in such a case the cæcal wall should contract in diameter without changing its length the epithelial coat would be thrown into deep longitudinal ridges and clefts that would extend from the base of the mucosa to the center of the lumen of the cæcum. These ridges would appear in transverse section as simple uncomplicated folds, i. e., very long slender finger-like projections of mucous epithelium into the lumen of the cæcum. These projections show, as might be expected, a uniform type of cell from tip to base, as shown in figure 8, plate XXVIII.

Now if the cæcum contracted in length it would bend and twist these longitudinal folds, and at the same time interrupt their continuity by producing transverse ridges and pockets in the epithelial coat, giving rise to a net-like appearance as seen from a surface view, a view not unlike that presented by Edinger^a in his figures 11 and 13b, and by Eggeling^b in figure 156. A cross section of a cæcum in this state always shows an extraordinary complexity of section throughout the epithelial coat, a complexity that was found extremely confusing until interpreted in the manner presented above.

^a Edinger, L.: op. cit., pl. 41.

^b Eggeling, H.: Dünndarmrelief und Ernährung bei Knochenfischen, Jenaische Zeitschrift, bd. 43, 1908, p. 416.

In the young salmon of fingerling size or smaller the extent of epithelium is relatively less; therefore the folds are simpler than has been described for the adult above. This is shown in a number of colored figures illustrating the process of fat absorption in young salmon, presented in a paper to follow. A similar epithelial folding has been described for other fishes, i. e., for the herring, *Muræna*, and the sturgeon.^a

The cells of the epithelial coat are of two types, and these are fairly uniformly distributed, i. e., the usual cylindrical cells, and the goblet cells. It is not desired to discuss here the question of the origin of goblet cells from the cylindrical cell, though the current views are supported by these observations.

The cylindrical cells are very slender in the adult, though less so in the younger fish, i. e., under 1 year old. Their size in a number of measurements made on paraffin sectioned material was from 45 to 63 μ long by 5 to 6 μ in diameter. They have slender oval nuclei located at the basal two-fifths of the cells. The cytoplasm of these cells presents no special structural features under ordinary conditions. If rapid absorption of fat is taking place it is shown by the special fat staining of fresh material to be present in the cylindrical cells. In paraffin preparations the fat is dissolved out and open empty spaces will appear in the cytoplasm (fig. 11, pl. XXVIII). No granules have been found and nothing comparable to the cells of Paneth have appeared in any of the sections.

The superficial borders of the cylindrical cells have a striated border marked by a homogeneous ground substance set with numerous fine striæ running vertical to the surface of the cell.

The goblet cells appear at tolerably regular intervals, though they are not numerous in the normal material. Their cell bodies seem a trifle larger on the average than the cylindrical cells. If the mucous of the goblet cell has not completely formed, then the striated border will be continuous over its surface. Many of these cells are present with the mucous content just beginning to discharge, in which state they are most prominent in appearance. The nuclei of the goblet cells lie nearer the bases of the cells than in the adjacent cylindrical cells. They also contain a greater amount of chromatin, hence stain more deeply with chromatin dyes.

The cells at the bottoms of the epithelial clefts or folds do not show any structural traits different from those on the folds projecting farthest into the lumen. This leads to the conclusion that there are no gland vestiges in the cæca of the salmon homologous with the glands of Lieberkühn, such as figured by Brass^a for the human vermiform appendix. Neither have any rudiments of these glands of the type described by Kingsbury^b for the small intestine of *Necturus* been found.

A certain number of wandering leucocytes are always found in the normal epithelial coat. In all the salmon material examined these white corpuscles are very small in size and are greatest in number in the basal region of the epithelial coat. They are not regularly distributed, but sometimes are present in groups of two or three. Their nuclei

^a Brass, A.: Atlas der Gewebelehre des Menschen, bd. I, 1896, Göttingen. Reference from Oppel, Mikroskopische Anatomie, bd. II.

^b Kingsbury, Benjamin F.: The histological structure of the enteron of *Necturus maculatus*. Proceedings American Microscopical Society, vol. 16, 1894, pp. 19-64.

are to be distinguished from the nuclei of the cylindrical epithelial cells by the fact that they are smaller in size and more round in outline and stain more intensely. The diameter of these cells is from 3 to 4 μ , while the long diameter of the oval nuclei of cylindrical cells is 5 to 6 μ , or even 10 μ in younger salmon. Occasionally through the epithelial coat scattered leucocytes are found in the outer third of the layer. In fact, these cells may be located at any level from the general nuclear region to the surface border of the coat. They do not appear to be, at least have not been observed, escaping from the epithelial coat into the intestinal cavity.

No eosinophile granule cells of any kind have been found in the alimentary epithelial coat of the king salmon. Such cells are described in this region for *Proteus* by Opper. This observation is of importance in association with the fact that granule cells of a type already described above compose the stratum granulosum.

Tunica propria.—The tunica propria of the cæca extends from the epithelial layer to the stratum compactum. Its extent varies greatly, and its outlines are very irregular. On the epithelial surface the tunica must follow the irregularities of that coat, while next the stratum compactum it is equally sinuous, owing to the great irregularity of surface of the stratum. The whole outline is not unlike that in the intestine, though simpler.

The tunica propria is a connective tissue structure carrying numerous blood vessels and supporting a number of special types of cells in its meshes. The connective tissue fibrils form an open meshwork of the usual areolar type. (See fig. 9, pl. xxviii.) At its epithelial boundary it forms a very definite limiting membrane, the basement membrane, on which the epithelial cell layer rests. From this basement membrane the more or less open meshwork of fibrils begins. Numerous oval nuclei appear in the ground substance. The compactness of the tissue and the relative number of nuclei vary extremely in the various specimens. Where the tunica propria extends up into a fold of epithelium its tissue usually appears somewhat more compact. Definite loops of small blood vessels and capillaries are present in these projections. Open tissue spaces are found both in the loops and in the broader expanses of the coat just within the stratum compactum, in the normal tissue these spaces being small in size. Beside the proper nuclei of the connective tissue there are relatively large numbers of nuclei of the white corpuscle type belonging to cells that have not yet been comparatively studied. These cells vary extremely in number in different areas and in different salmon.

The small arteries and veins, as well as the capillaries, are readily distinguished by the red corpuscles, which possess characteristic oval nuclei that take certain dyes in a differential way. Here and there are present certain large cells with a lightly stained cell body and a characteristic large nucleus, the identity of which has not yet been determined.

Lying just within the stratum compactum are scattered granule cells. These granule cells usually lie next the stratum compactum, sometimes in its loops, but occasionally may be found near the deeper loops of basement membrane, never in the epithelial coat. In fasting salmon this group of granule cells is more prominent.

Stratum compactum.—The stratum compactum is always present in the cæca of the king salmon. It is a striking structure and always stands out prominently in every microscopic section. Under the low magnification it appears as a broad wavy band extending around the circumference of the cæcum and lying within the muscular and external to the tunica propria coat.

The stratum is wavy in appearance, whether the section be transverse or longitudinal, but the extent of the folds which give rise to this phenomenon varies with the distension of the cæcum. Apparently the more contracted the organ as a whole the deeper the sinuosities of the stratum compactum. The stratum is a fairly uniform band, i. e., its thickness is relatively constant, varying between 12 and 16 μ .

Its structure has been described in other forms by several investigators, notably Mall.^a Gulland^b says that "a well-marked stratum compactum" is present in the Atlantic salmon. In the king salmon the stratum compactum is a homogeneous layer of fibrous connective tissue. It gives a characteristic staining with Mallory's connective tissue stain, but shows no fibrillar structure. On its surface the stratum of the cæca gives rise to a few smaller strands which extend out into the tunica propria on the one hand and form the network extending to the circular muscle coat on the other. These strands, especially in the latter case, form a supporting network for the special granule cells of the region. No nuclei are present in the body of the stratum compactum, but lying along its surface, especially on the surface next the tunica propria, a few nuclei are found. These nuclei are irregularly ovoid in shape, and appear to be embedded in a thin layer of tissue lying on the surface of the homogeneous portion of the stratum compactum. This layer stains a trifle more intensely than does the main body of the layer.

The stratum compactum is not present in the alimentary tract of all fishes, and why it should be so prominent a structure in the case of the king salmon remains a question. The coat is dense and it forms an uninterrupted layer (except where blood vessels penetrate from the outer to the inner structures of the cæcum). When a cæcum is widely distended the stratum is comparatively even and smooth in appearance. When the cæcum is contracted it is thrown into deep sinuous folds, no matter in what plane the section may lie. Its function is probably best explained by Oppel,^c who suggests that this is the supporting membrane for the structures of the entire organ. The fact that the stratum compactum is a homogeneous uninterrupted sheet seems to have further significance than that assigned by Oppel. The fat studies described in a later paper suggest that this structure may be concerned in the process of the absorption of the food products by the cæcum.

Stratum granulosum.—The cæca have a characteristic layer of granule cells bearing the usual relations to the stratum compactum and its network, i. e., the relation described

^a F. P. Mall: Reticulated tissue and its relation to the connective tissue fibrils. *The Johns Hopkins Hospital Reports*, vol. 1, 1896. Baltimore.

^b Paton, D. Noël: Investigations of the life history of salmon, art. 3, The minute structure of the digestive tract of the salmon, and the changes that occur in it in fresh water, by G. Lovell Gulland. Report of the Fisheries Board for Scotland, 1898.

^c Oppel, A.: Beiträge zur Anatomie des *Proteus anguineus*. I. Vom Verdauungstraktus. II. Von den Lungen, *Archiv, für mikroskopische Anatomie*, bd. 34, 1889, p. 511-572.

for both the stomach and the intestine. This layer of granule cells is very prominent in the pyloric cæca of the king salmon. Normally the layer is from two to four cells deep between the outer surface of the stratum compactum and the circular muscle coat. These cells are supported by the delicate strands of the outer surface of the stratum compactum. A few granule cells are located on the inner wall of the stratum compactum and occasional ones are found in the tunica propria, as mentioned above.

The numerous relatively large granule cells suggest Oppel's granule cells of *Proteus* in structural characteristics. The granule cells of the king salmon, however, have not been found in the epithelial coat, though under pathological conditions they undoubtedly do wander into other near-by regions. Gulland says, speaking of the pyloric appendages and the intestine: "In both structures the eosinophile leucocytes are numerous, but are to be found mainly in the connective tissue about the stratum compactum." In discussing these cells in connection with the structure of the stomach attention was called to the fact that Gulland figured cells of undoubtedly the same type as present in the king salmon. But I must again assert that these can not be blood leucocytes of the eosinophile or any other type.

The granule cells of the king salmon cæca have small round nuclei placed more or less eccentric with reference to the center of the cell. The cell body itself varies extremely in outline. In the majority of instances this outline is that of a broad oval, but where a cell is located in a restricted mesh its shape is adapted to conform to the space. This is especially to be noted in those cells present in the tunica propria.

In a section of a cæcum of a Monterey salmon taken June 23, 1911, the following measurements of granule cells are noted: 8 by 12, 8 by 10, 5 by 13, 8 by 14, and 9 by 14 μ . The special characteristic of the granule cells is the presence in the cytoplasm of large refractive granules. These granules stain with eosin, with Mallory's stain, taking especially the Bismarck brown but occasionally the acid fuchsin. They stain sharply with iron hæmatoxylin. The granules are very evenly distributed throughout the cytoplasm. The cells outside the stratum compactum seem more uniformly crowded with granules by whatever method of staining they be studied, and more densely granular than in the granule cells of the stomach. Those scattered cells that are present in the tunica propria are the ones that present the greatest irregularity in the distribution of the granules. A greater irregularity in outline suggests that the cells are amoeboid. In one or sometimes both poles of these irregularly shaped cells the granules are fewer in number, though the difference is only slight. Also in the smaller cells there are on the average fewer granules than in the larger. The number of granule cells in the normal tissue is such that the connective tissue meshes seem about one-half filled with the cells. In the relatively distended cæcum the total thickness of the layer is less. These points are mentioned for comparison with the structural condition found in degenerated cæca in which the number and relations of the granule cells differ sharply from the normal Monterey salmon type, as will be described in a paper to follow.

MUSCULAR COATS.

The muscular coats are the inner circular and the outer longitudinal muscles. The two coats are not so thick as in the intestinal wall or in the thick muscular walls of the stomach. But they are on the whole very regular and uniform.

Muscularis circularis.—The circularis is thicker than the longitudinalis in the salmon cæcum in the approximate ratio of 3 to 2. The coat is composed of relatively long, smooth muscle fibers. When the cæcum is distended the number of fibers present in the total diameter of this coat in a transverse section is only from 8 to 10, often less. Numerous capillaries are always present. Very rarely in the normal animal will one find a granule cell in the spaces of the muscle fibers of the circular muscle coat.

Just at the base of the cæcum the muscle is a little thicker and the lumen usually smaller. The structure shows all the appearances suggesting a degree of valvelike action capable of influencing the filling or emptying of the cæcum from or into the cavity of the pyloric intestine out of which it originates.

Muscularis longitudinalis.—The longitudinalis is a thin sheet of smooth muscle, the outermost of the muscle coats. In the king salmon the longitudinal coat varies in thickness according to the distension of the tube, but on an average it is from 5 to 8 fibers thick.

This coat is chiefly distinguished by its vascularity. Relatively large veins are found at intervals in the coat and occasionally a section will show arterioles entering the cæcum from the exterior, penetrating this coat to distribute branches out in the space between the two muscle coats. In the neighborhood of these blood vessels there is connective tissue in relatively large amounts, an arrangement which tends to break up the continuity of the muscular sheet.

On the inner surface of the longitudinal muscle coat between it and the circular muscle fibers, sections reveal the presence of numerous nerve cells and fibers of the plexus of Auerbach. In the individual ganglia of this plexus there are only a few nerve cells.

SEROUS COAT.

The serous coat of the cylindrical cæca of the king salmon consists of a single layer of squamous epithelial cells resting on a subserous connective tissue base. In the normal tissue these cells are extremely thin and attenuated. Their boundaries are difficult to measure in transverse section, but the extent is from 10 to 12 μ . The nuclei are spindle shaped, having a diameter of about 1 μ and a length of about 5 μ . In many specimens the serous cells are more cubical in outline and the coat is correspondingly thicker.

DESCRIPTION OF FIGURES.

The 11 figures presented in illustration of this paper were drawn for me by Mr. George T. Kline, biological artist of the University of Missouri, to whom I am indebted for skill and painstaking care in the interpretation of the specimens represented.

LIST OF ABBREVIATIONS USED.

Bl. v.	Blood vessel.	M. muc.	Muscularis mucosa.
Col. ep.	Columnar epithelium.	Neck c.	Neck cells.
Fat vac.	Fat vacuoles.	Str. comp.	Stratum compactum.
Gast. gl.	Gastric glands.	Str. gran.	Stratum granulosum.
Goblet c.	Goblet cell.	Submu.	Submucosa.
M. circ.	Muscularis circularis.	Tu. pr.	Tunica propria.
M. long.	Muscularis longitudinalis.	Wh. corp.	White corpuscle.

PLATE XXV.

FIG. 1.—This outline figure of the adult salmon is presented especially to show the external appearance of the viscera and the space relations of its parts. A segment of the left ventral wall is removed, exposing the organs in their natural position. The drawing is a semitransparency. The parts to which special attention is called are:

1. The liver, filling the anterior portion of the body cavity.
2. The cardiac loop of the stomach. The index figure is placed over the anterior portion of the posterior limb of the intestine shown as a transparency through the thickness of the stomach.
3. The pyloric limb of the stomach. The numeral is placed over the extreme anterior end and very near the constriction which is the location of the pyloric valve.
4. The pyloric intestine.
- 4'. The extreme posterior end of the intestine.
5. The pyloric cæca.
- 5'. Marks a cæcum that is almost surrounded by pancreas.
6. Pancreatic gland.
7. The spleen.
8. The long strap-like testes.
9. The ventricle.

Note that the pancreas is of the diffuse type of gland and is attached to the surfaces of, and lying among, the pyloric cæca. The gland is omitted over the cæca of the anterior loop. One-fourth natural size.

PLATE XXVI.

FIG. 2.—Cross section of a normal empty stomach from salmon no. 21, Monterey, Cal. This low-power figure shows the relation of the gross parts, also the compact folding of the glandular portion of the stomach into longitudinal rugæ when it is empty. Magnification, $\times 4$.

FIG. 3.—A low-power drawing of a transverse section of the stomach wall, showing the histological relations of the various coats. For the interpretation of the abbreviations used to designate the parts, refer to the list of abbreviations above. Camera outlines. Magnification, Leitz ocular 1, objective 3.

FIG. 4.—A representation of a highly magnified gastric gland. To the left of the figure are three transverse sections of the gland tubes, one showing a deep oval. To the right of the figure is a longitudinal section of a short loop of gland cells just at the point where transition to neck cells takes place. The gastric-gland cells are loaded with granules from base to free margin. The granules vary considerably in size, as discussed in the text. The neck cells are free of granules. Camera lucida outlines. Magnification, Leitz ocular 2, objective 1/12.

PLATE XXVII.

FIG. 5.—A quadrant of a transverse section of the intestine taken from a salmon (no. 117) from Ilwaco, Wash. This salmon was in the first stage of the migration fast, hence the relative thickness of the different layers is undoubtedly somewhat different from the normal. However, it shows the relative position of the layers and the relative complexity of folding of the mucous epithelial coat. Camera outlines. Magnification, Leitz ocular 2, objective 3 (lower lens removed).

FIG. 6.—A superficial sketch of a single cæcum chosen from the longer group at the beginning of the pyloric intestine of a feeding salmon from Monterey, Cal. This cæcum is 8 by 160 mm. The smaller cæca have the same relative outlines as the larger. Magnification, $\times 1$.

FIG. 7.—A transverse section of a normal cæcum from salmon no. 22, Monterey, Cal. This section shows the relation of the different coats, also is especially good to show the enormous extent and complex outlines of the mucous epithelial coat. The wavy band is the stratum compactum which characterizes not only the cæca, but the intestine and the stomach as well. Camera lucida outlines. Magnification, Leitz ocular 1, objective 3 (lower lens removed).

PLATE XXVIII.

FIG. 8.—A portion of the wall of the cæcum of a normal feeding salmon (1911 series, no. 11) from Monterey, Cal. The magnification in this figure is chosen to bring out the general histological relationships of the various parts. When the section is at exact right angles, as shown in the folds at the left, it presents an almost diagrammatic regularity. The folds to the right of the figure are complicated, hence many of the cells are cut at oblique angles. The muscular walls are relatively thin in this section, a condition that exists when the cæca are distended with food material. Magnification, Leitz ocular 1, objective 3.

FIG. 9.—A highly magnified section through the wall of a pyloric cæcum taken just at the bottom of a deep fold. The legend is sufficient to identify the parts. Particular attention is called to the relations of the stratum compactum. This dense connective tissue structure is marked on its external surface by a network of strands inclosing the cells of the stratum granulosum. These cells are characterized by the uniform and dense loading with highly refractive granules which usually completely obscure the small eccentric nucleus. Camera outlines. Magnification, Leitz ocular 1, objective 7.

FIG. 10.—A portion of the cylindrical epithelium and the substratum of the tunica propria highly magnified from a feeding salmon (no. 22) from Monterey, Cal. The figure presents a camera lucida outline of the cells, showing their relative size, structure, the relations of the nuclei, etc. Two goblet cells in different stages of maturity are shown. In the tunica propria there is a capillary in which lies the cross section of a red-blood corpuscle cut somewhat excentric to the nucleus. Camera lucida outlines. Magnification, Leitz ocular 4, objective 1/12.

FIG. 11.—Showing a highly magnified group of columnar epithelial cells from the pyloric cæcum of a Monterey salmon in the active stage of absorption. The fat vacuoles are relatively large and numerous in the outer third of the cells. They are present, but more scattered, in the inner limbs of the cells. In preparations made with a positive fat stain applied to fresh material these vacuoles are proven to contain fat droplets. Magnification, Leitz ocular 4, objective 1/12.

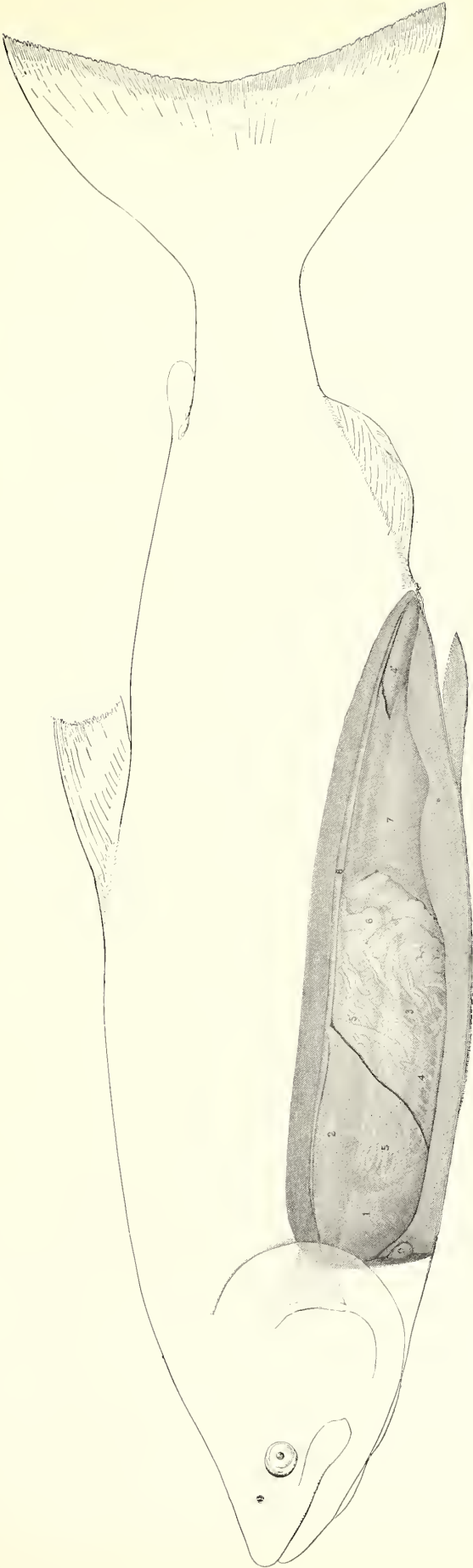


FIG. 1.

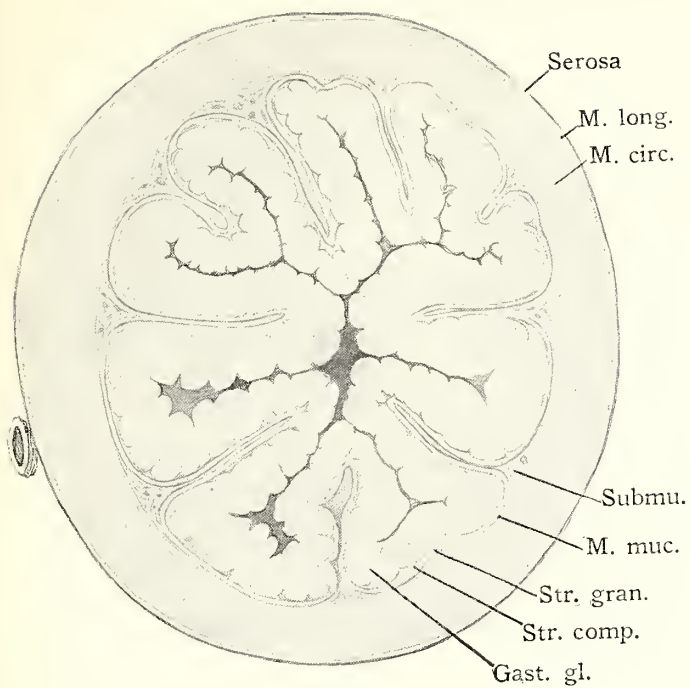


FIG. 2.

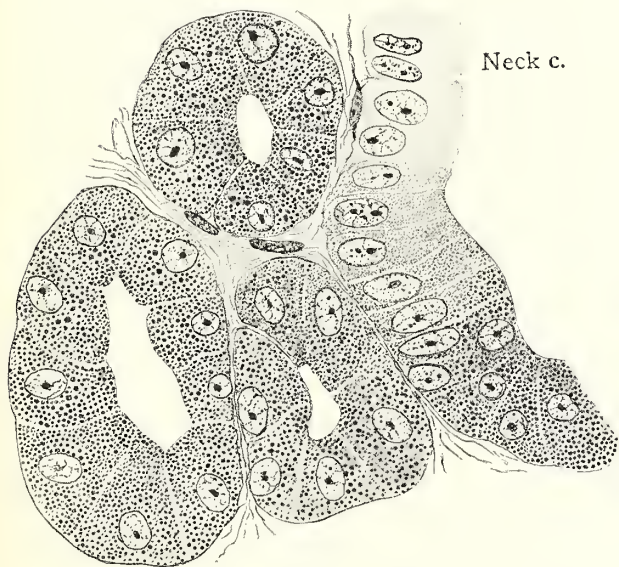


FIG. 4.

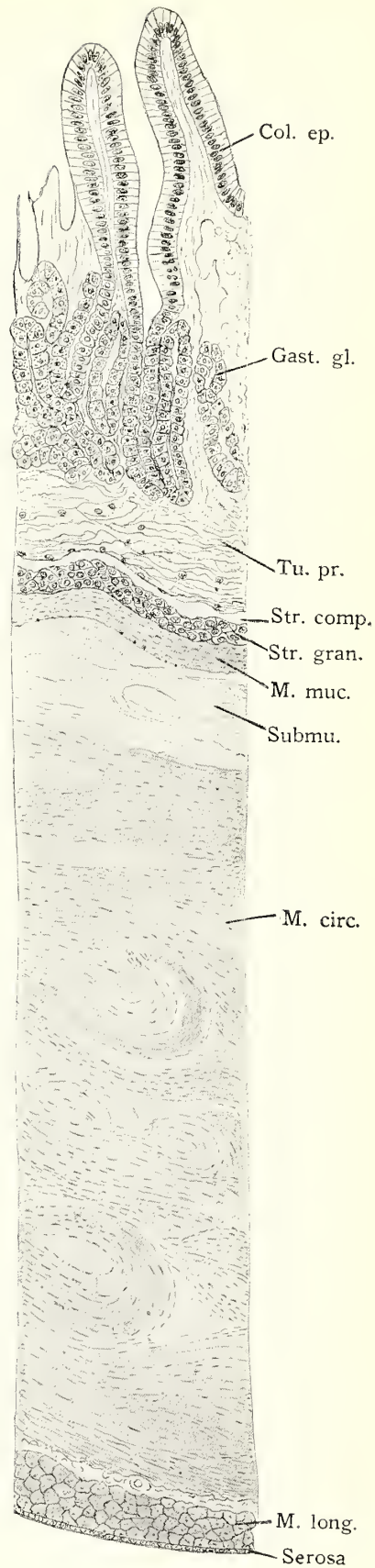


FIG. 3.

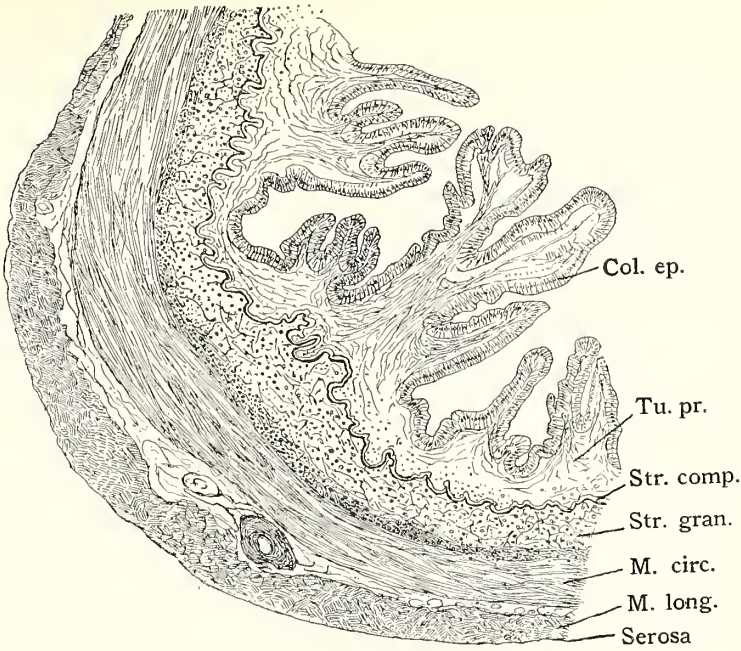


FIG. 5.

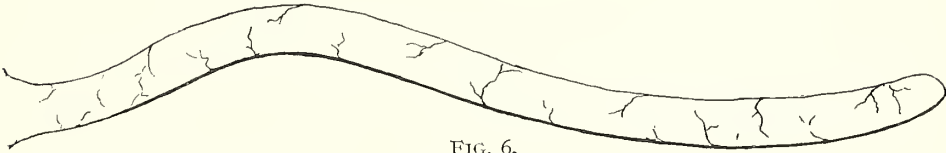


FIG. 6.

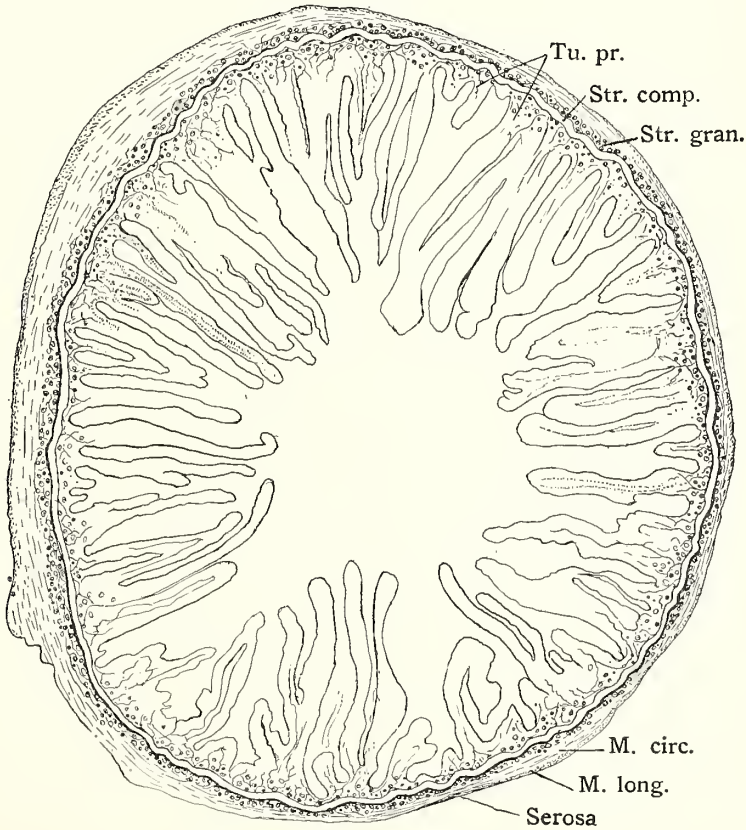


FIG. 7.

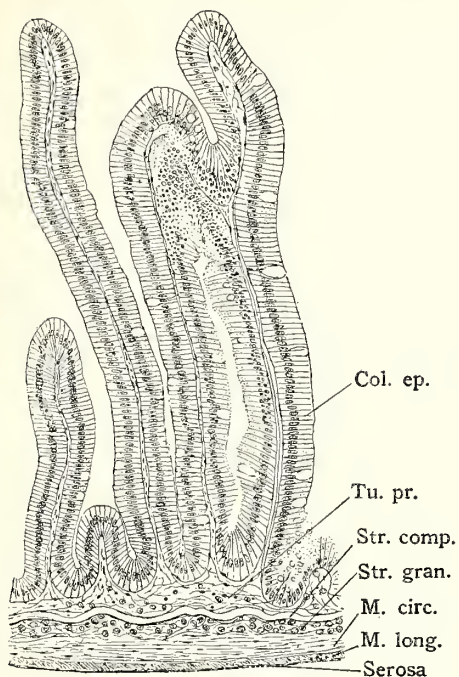


FIG. 8.

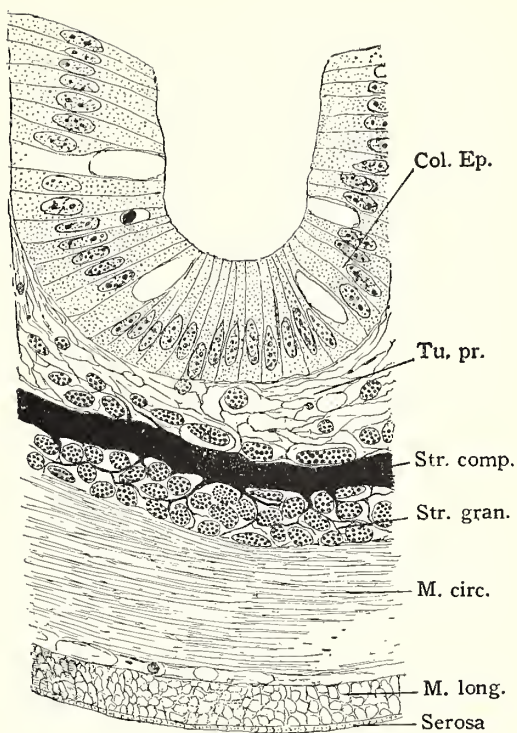


FIG. 9.

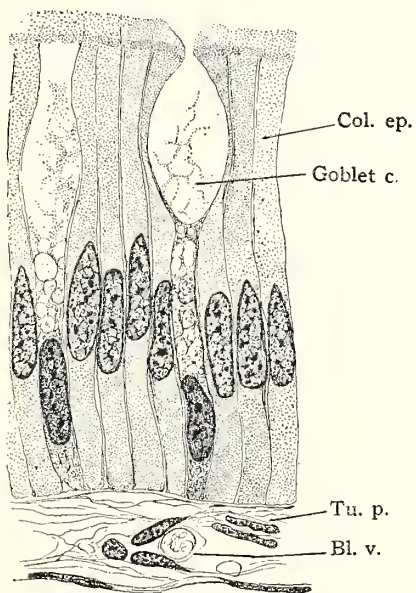


FIG. 10.

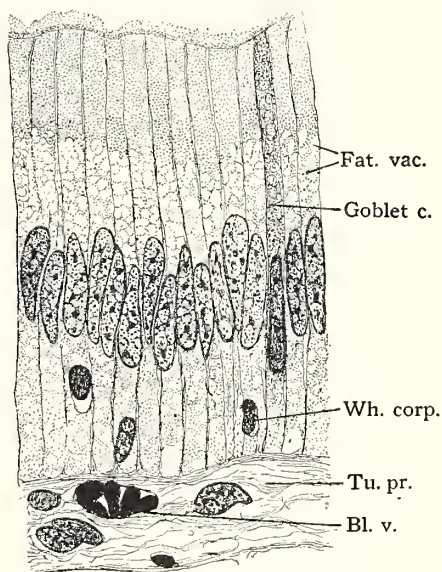


FIG. 11.

NOTES ON THE NATURAL HOSTS OF FRESH-WATER MUSSELS



By Thaddeus Surber

Assistant, United States Biological Laboratory, Fairport, Iowa

NOTES ON THE NATURAL HOSTS OF FRESH-WATER MUSSELS.

By THADDEUS SURBER,

Assistant, United States Biological Laboratory, Fairport, Iowa.

A study of the conditions pertaining to natural infection of fishes with the larvæ of fresh-water mussels was begun by the writer, under the direction of Dr. R. E. Coker, at the Fairport laboratory in 1910, but was interrupted by assignment to other work, and, while an effort was made to resume the study in 1911, but little was done owing to more pressing duty demanding the time. From the last week in June till the close of November, 1912, however, work was pushed rapidly, 2,815 fish being critically examined, and considerable knowledge gained in regard to certain mussel species.

The observations given in this paper indicate that the natural hosts of our fresh-water mussels are divisible into two classes—i. e., specific distributors of particular species, and accidental or occasional hosts. To the first class belong the skipjack (*Pomolobus chrysochloris*), distributor of the niggerhead (*Quadrula ebena*); the sheepshead (*Aplodinotus grunniens*), distributor of the paper-shell (*Lampsilis laevissima*) and the deer-toe (*L. donaciformis*); and the shovel-nose sturgeon (*Scaphirhynchus platyrhynchus*), distributor of the slough sand-shell (*L. fallaciosa*). The sauger (*Stizostedion canadense*) may belong here as distributor of another sand-shell (*L. higginsii*), but it would be unwise to conclude this on the strength of a single specimen. To the second class, in order of their importance, belong the crappie (*Pomoxis annularis*), which has been observed to carry six species; the sauger, carrying four species; two sunfishes (*A. pomotis cyanellus* and *Lepomis pallidus*) each carrying three; the strawberry bass (*Pomoxis sparoides*), two species; and another sunfish (*Lepomis humilis*) and the white bass (*Roccus chrysops*), one each. A catfish (*Ameiurus natalis*) carries a few glochidia of the *Quadrula* type, but I have not been able to identify the species, owing to accidental loss of material.

Upon consideration, the first class (specific distributors) will be found to agree closely in geographical range with the species of which it is the host, as might be expected. This, of course, is not an original theory, but was advanced years ago by Simpson,^a and I am convinced that he was right in his conjecture, and to that end shall attempt to show that it is the case in at least three species of our mussels.

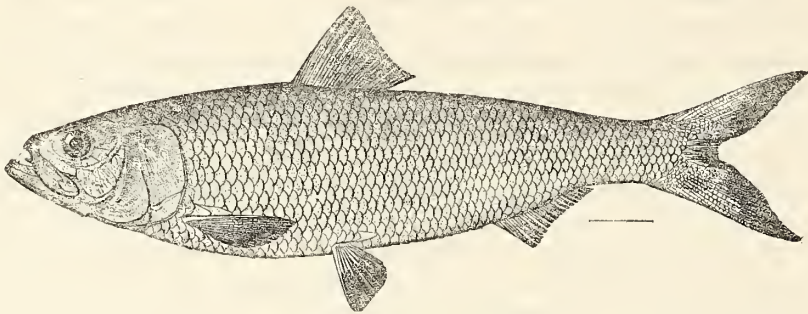
The second class of infections, accidental or occasional hosts, need not be taken up systematically at this time. Reference can be made to table II, however, which shows the species and number of fishes that were observed to be infected with the various species of mussels.

^aSimpson, Charles T.: The pearly fresh-water mussels of the United States; their habits, enemies, and diseases, with suggestions for their protection. Bulletin U. S. Fish Commission, vol. XVIII (1898), p. 282.

HOSTS THAT ARE SPECIFIC DISTRIBUTORS.

SKIPJACK (*Pomolobus chrysochloris*).

This beautiful fish, variously known as "skipjack," "herring," and, at New Boston, Ill., as "nail-rod," is of rather erratic habits, being abundant at times at certain places along the Mississippi, and at others one of the rarest of fishes. The fishermen at New Boston tell me that at times it is very abundant there, usually in September, but at other times entirely absent. Mr. Will Morris, of Fairport, informs me that a number of years ago while in a flatboat lying off the point of an island in the Mississippi near Lansing, Iowa, he caught these fish nearly as fast as he could pull them aboard, using a common spoon hook. They take live minnows readily also, but the New Boston fishermen tell me are very rarely caught in a trammel net, most of those taken being secured by means of seines, or hook-and-line fishing in the vicinity of the wing dams. Frequenting the most rapid water in the river, particularly that having a rocky, gravelly bottom,

Skipjack (*Pomolobus chrysochloris*).

the skipjack is predaceous in habits, feeding mostly on minnows, and Forbes tells us the young feed on insects. I do not believe this fish is nearly so rare as we might infer from Dr. Forbes's records as given in his "Fishes of Illinois," but that the fishermen pay no attention to it at all, considering it a nuisance and immediately throwing overboard all that are caught.

The geographical range of this fish, as given by Jordan and Evermann, is "Mississippi Valley, etc., abundant and resident in larger streams; introduced into Great Lakes. Also in Gulf of Mexico."

The range of *Q. ebena* as given by Simpson is "Mississippi drainage generally except its western portion; Alabama and Tombigbee Rivers; northeast Texas(?)."

The importance of the skipjack to mussel culturists prompts the hope that it may be possible in the course of time to propagate this fish artificially, and in the meantime it is suggested to those who believe in the introduction of western forms into eastern waters to try one of its eastern congeners, *P. pseudoharengus* or *P. æstivalis* as an experimental host for this desirable mussel. The introduction of mussels into other waters by

transportation of the infected fish, entirely feasible with some fish,^a would not be possible in this case, as the skipjack is very delicate and will not admit of handling during the warm summer months.

SHEEPSHEAD (*Aplodinotus grunniens*).

From its feeding habits we should expect to find this fish more often infected than any other species. In writing of it Dr. Forbes^b says:

This fish is of a sluggish habit, living on the bottom of muddy waters, where it feeds especially on mollusks, the shells first being crushed by the powerful, paved millstone-like, pharyngeal jaws. Often the stomach contains only the soft bodies and opercula of gastropod mollusks, the crushed shells having been thrown out. Crawfishes are also sometimes found in the food. Half-grown specimens feed largely on aquatic insects, especially the larvæ of May-flies, mingling larger and larger proportions of mollusks with this food as they increase in size, until they come finally to depend almost wholly upon water snails and the relatively thin-shelled clams.

As it is known to be the specific host for both *L. lævissima* and *P. donaciformis*, it is of rather more than usual interest.^c It can no doubt readily crush the papery shells of *lævissima*, and, from their small size, swallow entire the shells of *donaciformis*, from which we can readily understand the enormous numbers that are attached to the gills of this fish.

The geographical range of the fish is given as "Great Lakes to Texas and Georgia; abundant in all lakes and large streams west of the Alleghanies and east of the plains" (Jordan and Evermann).

Simpson gives the ranges of the two mussels as follows:

L. lævissima: "Mississippi drainage generally; eastern Texas, southern Michigan, western New York."

^a Dr. Ortmann, in an interesting article in a recent issue of "The Nautilus" (vol. xxvi, p. 51), records the accidental introduction of the "pockethook" (*L. ventricosa*) into the upper Potomac drainage in Maryland and West Virginia.

^b Forbes, S. A.: Fishes of Illinois, Natural History Survey of Illinois, State Laboratory of Natural History, vol. iii, p. 324.

^c Since the above was written the author has had the opportunity to examine a number of fish taken by him in White and Cache rivers near Clarendon, Arkansas. During the first half of January (1913) 18 specimens of *Aplodinotus grunniens* were secured, eight of which bore natural infections, and from the number of glochidia borne by each fish I should accept it as the specific host of *Lampsilis (Proptera) purpurata*; five examples were infected on the gills and another both on gills and caudal fin. The cysts are very large and consequently very noticeable. While all are not of the same development the growth in the majority of cases is very marked; the infant mussels have assumed about the development indicated in the figure of *lævissima* shown in figure 2, plate XXIX. It is presumed these fish became infected some time during the autumn, but as many gravid mussels of this species, all with active glochidia, were taken during January, some may have become infected more recently. In these infections the number of infant mussels borne by individual fish varied from 68 to as many as 500 in two cases. The glochidium of *purpurata* resembles very closely that of *L. (Proptera) alata* both in shape and size, measuring 0.200 by 0.360 mm.; the hooks, however, are better developed than in *alata*.

A still more interesting discovery is the finding of a number of glochidia of *Quadrula heros*, heavily encysted and of considerable development, on the fins of two of these *Aplodinotus*. This glochidium being of the hookless type it was naturally supposed to be a gill parasite, but this does not seem to be the case, as none were found on the gills of the fish.

In the White River material is also a specimen of rock bass (*Ambloplites rupestris*) carrying on its gills six glochidia of *Arcidens confragosa* beautifully encysted and of considerable development. The hooked glochidium of *Arcidens* is closely related, in form at least, to the *Anodonta* group, one species of which (*cataracta*), according to Lefevre and Curtis (Bulletin U. S. Bureau of Fisheries, vol. xxx, p. 158), would not metamorphose on the gills of the carp. A crappie (*P. annularis*) was also secured bearing the same species on the gills; but this mussel is probably more frequently found on the fins of fishes, as two hickory shad (*Dorosoma cepedianum*) were taken bearing considerable numbers on the fin margins, particularly the caudal, where they are deeply embedded in the epithelium.

P. donaciformis: "Mississippi drainage generally; Alabama River area; southwest to the Trinity River, Tex.; Michigan."

In artificial infections this fish takes readily almost any glochidia of the *Lampsilis* group, but with indifferent results, more probably due to the difficulty of handling it in hot weather than from any other cause.

SHOVEL-NOSE STURGEON (*Scaphirhynchus platyrhynchus*).

Sturgeons as a rule are bottom feeders, and this species is no exception, so that we should expect to find it very frequently infected. Such, however, does not seem to be the case. The heavy gill filaments of this fish render difficult the detection of glochidia; therefore all that were obtainable were carefully gone over, and it is not believed any were overlooked which were carrying larvæ in any numbers. On October 15 and again on November 7 specimens were taken holding larvæ of *Lampsilis fallaciosa*, and these were in sufficient numbers to indicate that it is the specific host of this particular species.

While it is unsafe probably to consider this fish the only distributor of *fallaciosa*, it is interesting to note the known geographical ranges of the two species, which is as follows:

S. platyrhynchus: "Mississippi Valley and streams of the Western and Southern States" (Jordan & Evermann).

L. fallaciosa: "Upper Mississippi drainage; south to the Cumberland River, Tennessee, and to Arkansas; Red River of the North?" (Simpson).

MUSSELS AS PARASITES.

We shall now consider the matter from another point of view, taking up in their order the various mussel species as parasites. It will be noted that all species considered in this study are gill parasites with one exception, *A. corpulenta*, and consequently nearly all of commercial value.

SLOP-BUCKET (*Anodonta corpulenta*).

But one fish has been taken bearing larvæ on the external parts, and this is found to be *corpulenta*. On November 10, 1910, along the river shore within the grounds of the biological station, a young skipjack about 3 inches in length was picked up which held 24 glochidia, mostly on the caudal fin, but a few on ventrals and pectorals. By reference to the accompanying figure (fig. 1, pl. XXIX) it will be noted that encystment is incomplete, though but a small portion of the dorsal edge of the shell protrudes, and that the infection is quite recent is further shown by the condition of development in the adductor muscle. This glochidium is saddled over the edge of the caudal fin and grasps two of the cartilaginous rays up almost to the adductor muscle; the other glochidia occupied relatively the same positions on the fins as shown in this figure.

YELLOW SAND-SHELL (*Lampsilis anodontoides*).

During the latter part of June and early in July this mussel was found on the two species of crappie and on *Apomotis cyanellus* and *Lepomis humilis*, but in such limited numbers that it is extremely doubtful if any of these fish are the actual host, as the greatest number occurring on any one species was six. As this time is the height of the spawning season of this particular mussel, and all the infections were recent, it is presumed they were more or less accidental.

Some sunfish infected artificially with glochidia of this mussel July 1, 1911, apparently took well and were deeply encysted at the end of three and three-fourths hours, but two days later not a single glochidium could be found on any of the fish, due probably to unfavorable conditions. On June 27, 1910, a lot of fish, chiefly *Pomoxis* and *Lepomis*, with a few *Micropterus*, *Aplodinotus*, and *Roccus* were infected and apparently took well, but the glochidia never completed their metamorphosis. However, on August 11, 1910, a few metamorphosed on a sunfish (*A. cyanellus*) in four days, about 1 per cent of those encysted.

SLOUGH SAND-SHELL (*Lampsilis fallaciosa*).

On June 27 a crappie (*P. annularis*) was taken holding 16 glochidia of this species, but it was not again found till October 15, when a sturgeon (*S. platyrhynchus*) was taken holding 125. On November 7 another sturgeon was taken holding 56.

This glochidium does not, as a rule, take very near the tips of the filaments in the sturgeon, but rather deep, a great many as deep as the fork of the filament, and encystment is very heavy. The October infection indicates but very slight development, or none at all; cysts enormous. Examination of the November infection reveals the fact that the adductor muscle is dividing and traces of the foot are clearly discernible. It is believed these sturgeon become infected sometime during September or October, and the metamorphosis would, therefore, not be completed till some time during the following spring.

HIGGINS SAND-SHELL (*Lampsilis higginsii*).

The only fish so far taken which unquestionably holds this glochidium is a specimen of *Stizostedion canadense* taken October 4, 1912; it holds approximately 600 glochidia. The infection was recent and no development is clearly indicated; cysts very heavy.

PAPER-SHELL (*Lampsilis lævissima*).

For the past three years we have been taking sheepshead (*Aplodinotus grunniens*) bearing enormous numbers of young *lævissima*, generally in a high state of development. The sheepshead, from its habits, should be expected to be found more frequently infected than most any other species of fish, yet the percentage of infected fish is small.

Only 2 per cent of the fish taken during the period from June to November were infected with this larva, the number carried by each fish varying from 112 to 850. It was hoped that a critical study of the material would indicate the period of parasitism, but such is not the case, though I am of opinion that it covers a period of nearly a year.

The only fish so far taken carrying what is apparently recent infection is one taken October 21, but only a few, about 1 per cent, are of this stage, i. e., the glochidium still simple. The next stage is indicated in specimens secured October 15, where the growth is quite decided, the infant mussel having assumed a nearly circular form when viewed from the side; this phase is clearly shown in figures 2 (side view) and 3 (postero or antero ventral view). In figure 2 the larval mussel is on the extreme tip of the gill filament, while figure 3 is encysted about 3 mm. back from the tip and on the flat side of the filament. Another fish, taken October 30, holds larval mussels in a more uniform state of development, of a stage clearly shown by figure 4; by reference to this figure it will be found that the young mussel has apparently grown more rapidly in length than in height, and that in the region of the umbones, both anteriorly and posteriorly, it has not grown at all, except in thickness, giving it a curious depressed effect there. Figure 4 exhibits the sharpness of the ventral points of the glochidial shell on the upper side, caused by the growth of the shell of the young mussel expanding the glochidial shell; in figure 5 a dorsal view is given of another specimen of the same relative development to show increase in thickness.

The greatest development seems to be reached during October, when they have assumed the shape and size indicated in figures 6 and 7, where it has increased three to four times in length over glochidium and the inflation (thickness) is so marked as to suggest anything but the parent shell, when viewed dorsally (fig. 7). This stage has been shown before (Coker and Surber, Biological Bulletin, vol. 20, p. 179-182, fig. 5, 6, and 7). It is believed that at this stage the parasitism is completed, or nearly so, and this belief is strengthened by the fact that on November 2 a fish was taken holding comparatively few (120) mussels and a number of ruptured cysts which had probably held others a very short time previously, though it is of course possible that the ruptures may have been caused by other parasites, but this is not deemed probable. We might infer from this that the fish became infected either the preceding spring (1912) or during September of the preceding year (1911), the latter seeming the more probable. *Lævis-sima* with ripe glochidia has been taken in the vicinity of Fairport during April, June, and September.

So far, this mussel has been found on but one other species of fish, the crappie, in which the same development is indicated as occurs in the sheepshead.

TABLE I.—NUMBER OF LARVAL *L. LÆVISSIMA* CARRIED BY THE HOST.

Species of fish.	Date secured.	Number of glochidia.	Locality.
<i>Aplodinotus grunniens</i>	June 16, 1910	670	Fairport, Iowa.
	Oct. 18, 1910	375	Do.
	Oct. 15, 1912	325	Do.
	Oct. 17, 1912	112	Do.
	Oct. 15, 1912	850	Do.
	Oct. 30, 1912	200	Do.
	Oct. 21, 1912	240	Do.
	Nov. 2, 1912	120	Do.
	Nov. 9, 1912	540	Do.
	Nov. 17, 1912	112	Do.
	Nov. 21, 1912	210	Do.
<i>Pomoxis annularis</i>			

MUCKET (*Lampsilis ligamentina*).

On the 26th of September a rather large *Roccus chrysops* was taken holding upward of 200 glochidia of this species; cysts are heavy but glochidia show no development at all, so that it is presumed to be a recent infection.

A great many other fish were taken during September and October, principally crappie and sunfish, infected with this mussel, but as the crew of the station were at work infecting and liberating fish with this larva, all were presumed to be artificial infections. No *Roccus* had been artificially infected previous to September 26, so that the above record is deemed permissible.

BLACK SAND-SHELL (*Lampsilis recta*).

The only time this mussel has been found a natural parasite was July 2, 1912, when a *Lepomis pallidus* was taken bearing 35 glochidia. The infection was recent, deeply encysted, and I have no doubt would have metamorphosed in a very short time, the fish being extremely strong and robust.

DEER-TOE (*Plagiola donaciformis*).

This small mussel, so far, seems to be found almost exclusively on the sheepshead, the only exception being a sauger taken quite recently. Discovered first at New Boston, Ill., in August, 1910, it has since been found at frequent intervals, both there and at Fairport.

The number of young mussels found on a fish varies considerably, but is usually great, a fish taken October 30 holding about 2,800, which is the greatest number found. The duration of parasitism is problematical; no fish have been found recently infected, all infections so far found being highly developed. As we have secured gravid mussels of this species with fully developed glochidia only during the latter part of July, it seems probable, and is possible, that the enormous development indicated occurs in the short space of two months, but this of course can only be proved by artificial infection of the specific host. Specimens of least development, so far known, are some taken July 20, 1911, one of which is shown in figure 8 (postero-dorsal view); this would indicate one of two facts, either that it was an infection of the previous year, in which case growth is comparatively slow, or that it was very recent and growth correspondingly rapid. On a fish taken August 16 occur 1,495 young mussels, the development of which is very great, far exceeding that shown previously in *levissima*; one in side view is shown by figure 9, which is found to have increased seven times in length, and about three and one-half times in depth over glochidial shell, yet all on this fish were not uniformly developed, as is shown in figure 10 (a). Figure 10 shows a portion of a filament with young mussels in situ, two of which are on the edge, while the other (a) is encysted on the flat side of the filament.

TABLE II.—NUMBER OF LARVAL *P. DONACIFORMIS* CARRIED BY THE HOST.

Species of fish.	Date secured.	Number of glochidia.	Locality.
<i>Aplodinotus grunniens</i>	Aug. 9, 1910	1,100	New Boston, Ill.
	Aug. 15, 1912	300	Do.
	Aug. 16, 1912	1,495	Do.
	.....do.....	1,200	Do.
	Aug. 15, 1912	76	Do.
	Aug. 22, 1912	2	Fairport, Iowa.
	Aug. 24, 1912	280	Do.
	Oct. 30, 1912	2,800	Do.
	Nov. 9, 1912	1,000	Do.
<i>Stizostedion canadense</i>.....	.....do.....	1,800	Do.

BUTTERFLY (*Plagiola securis*).

But a single glochidium, well encysted, has been found by the writer, this being found on a sunfish (*Apomotis cyanellus*) taken July 1, 1912; no development was indicated.

Experiments in artificial infection of the black bass, crappie, sunfish, and catfish with this larva have proved unfavorable, so that we must conclude the specific host is as yet unknown.

BULLHEAD, SHEEPNOSE (*Pleurobema asopa*).

A sauger (*S. canadense*) was taken July 20, 1911, holding 17 glochidia of this mussel. As the anterior and posterior adductor muscles were clearly defined and the foot more or less conspicuous, indications are that this fish is at least an occasional host of this larva. As the mussel itself is not at all common, the sauger may eventually prove to be the specific host. An infection is shown in figure 17.

NIGGERHEAD (*Quadrula ebena*).

The discovery of the specific host of this mussel on August 13, 1912, was a great gratification, occurring as it did after almost three years' experimentation. Repeated failures in obtaining artificial infections with all the species of fish obtainable in the vicinity of Fairport led me to search for fish not previously taken, of which the skipjack (*P. chrysochloris*) was about the only one remaining. The taking of a specimen of this fish, June 18, 1910, by H. Walton Clark, was overlooked till after the August, 1912, material was identified, when his note was looked up and later the fish itself secured and found to be heavily infected. Mr. Clark, while recognizing at the time of taking that his 1910 specimen was carrying glochidia in great numbers, was unable to identify the species of mussel owing to lack of material, no glochidia of *Q. ebena* being available at that time for comparison. Owing to the great commercial value of this shell, which is exceeded by none, the final discovery of the host is of far-reaching importance.

During the season of 1912, 15 specimens of *Pomolobus* were secured in the vicinity of Fairport and New Boston, the 5 specimens secured during August all bearing glochidia in large numbers, ranging from 1,895 to 3,740 for each fish. During this month little development of the glochidia was shown which would indicate recent infection, but a

specimen taken at Fairport, September 11, had only 48 glochidia remaining, and two specimens out of a total of nine taken at New Boston, September 24, held 26 and 31, respectively, all the September material indicating much development. The same results are shown by some material from the upper Mississippi which Mr. W. B. Gorham secured while with the reclamation work of the steamer *Curlew*, when, on August 26, at La Crosse, Wis., he secured one fish holding 365 glochidia, well along in development, and another fish at Genoa, Wis., September 23, with development about completed. In the vicinity of Fairport *ebena* has been secured with well-developed embryos during the last week in May and during June, July, and August. This would indicate a comparatively rapid metamorphosis, which, in my opinion at least, does not much, if at all, exceed two months.

A study of the material shows us that *ebena* undergoes no important increase in size of shell, and consequently no change in form, during metamorphosis. Figure 11 shows a glochidium (side view) on the edge of a filament. By reference to the figure it will be noted that considerable development is indicated, the posterior adductor showing in place, and the foot considerably developed; this was taken August 13, and figure 12 shows dorsal and ventral views of the same development. In the specimens taken September 24, shown by figure 13, the development is very clearly defined, the foot having reached what might be considered normal size, while the position of the anterior and posterior adductors and the protractor pedis is distinct; it is believed this young mussel would have left its host in a very short time. In the specimens taken June 18, 1910, practically no development at all has occurred; the distal third of a gill filament of this infection is shown in figure 14.

Particular attention is called to figures 12 and 13, where the cysts are shown off to one side of the young mussel, a characteristic feature of those which have attained sufficient development. It seems the young mussel has shifted its position, migrating as it were from its normal position in the cyst to a new one among the delicate filaments, disarranging them as indicated in the figure (12) on the right side; this movement is preliminary to its ultimate freedom. The young mussels are now lying on the surface of the filament beneath the mucous membrane covering it, while the epithelial cells forming the cyst proper remain unbroken, so that it has evidently pushed along beneath the membranaceous covering to its present position, the membrane having now adapted itself to the new conditions and formed, as it were, a new cyst which covers the entire filament and gives to the parasite much increased freedom of movement. This condition is more clearly shown by reference to figure 18, where the distinctly swollen area comprising the new cyst is accentuated, though the magnification in this figure is much less than indicated in figures 12 or 13.

In the more recent infections—that is, the young still in the glochidial stage, as shown by figure 14—this remarkable condition does not exist, the development being such that the animal has no power of locomotion as yet. On the other hand, in specimens taken during September, there are many cysts having the appearance of these shown in figure 13, simple, hollow, globular areas suggesting small tumors, unmistakably the former abode of some young mussel which has completed its metamorphosis and departed with-

out apparent serious injury to the cyst. This condition is interesting, nothing like it having previously been noted in the parasitism of any of our mussels, so far as I know, and the causes leading up to it will bear careful investigation. This can be done only by a thorough study of the relations existing between host and parasite, in which connection it will be well to study in detail the structure of the gills of the host.

TABLE III.—NUMBER OF LARVAL *Q. EBENA* CARRIED BY THE HOST.

Species of fish.	Date secured.	Number of glochidia.	Locality.
Pomolobus chrysochloris.....	Aug. 13, 1912	2, 100	Pearl Slough, Fairport.
.....do.....	.....do.....	3, 740	Do.
.....do.....	Aug. 14, 1912	1, 895	Buttermilk Slough, Fairport.
.....do.....	.....do.....	2, 700	Upper end Geneva Island.
.....do.....	Aug. 17, 1912	3, 200	New Boston, Ill.
.....do.....	Aug. 26, 1912	365	La Crosse, Wis.
.....do.....	Sept. 11, 1912	48	Fairport, Iowa.
.....do.....	Sept. 24, 1912	26	New Boston, Ill.
.....do.....	.....do.....	31	Do.
.....do.....	Sept. 23, 1912	9	Geuoa, Wis.
.....do.....	June 18, 1910	2, 570	Fairport, Iowa.

MONKEY-FACE (*Quadrula metanevra*).

During the early part of July five blue sunfish (*Lepomis pallidus*) and one green sunfish (*A. cyanellus*) were taken bearing a comparatively small number of glochidia of this mussel. The two heaviest infections are one of 50, the other of 69, and it is therefore probable the sunfishes may be found to be the specific hosts of this mussel. By reference to figure 15 it will be found that one of the infections, taken July 2, is developing, the adductors having become clearly defined and rudiments of the foot apparent. No change in form nor increase in size of shell is anticipated in this species.

TABLE IV.—NUMBER OF LARVAL *Q. METANEVRA* CARRIED BY THE HOST.

Species of fish.	Date secured.	Number of glochidia.	Locality.
Lepomis pallidus.....	July 1, 1912	6	Fairport, Iowa.
.....do.....	July 2, 1912	50	Do.
.....do.....	.....do.....	1	Do.
.....do.....	.....do.....	6	Do.
.....do.....	.....do.....	69	Do.
.....do.....	.....do.....	15	Do.

BLUE-POINT; THREE-RIDGE (*Quadrula plicata*).

The only fish so far taken infected with this species was on June 28, 1912, when a sauger (*S. canadense*) carrying 28 and a crappie (*P. annularis*) 4 glochidia were secured. The development is decidedly progressing as indicated in figure 16, where the foot and both adductor muscles are clearly defined. The figure (16) is a glochidium attached to edge of gill filament of the sauger.

PIMPLE-BACK (*Quadrula pustulata*).

But two glochidia of this species have so far been detected and this on a crappie (*P. annularis*) taken September 12, 1912. While it is rather late in the season to expect to find this mussel still parasitic, it is not believed that the identification is wrong; yet the development should have progressed more rapidly than is the case in this instance.

PIMPLE-BACK (*Quadrula pustulosa*).

October seems extremely late to find any *Quadrulas* persisting, but the gills of a crappie taken the 17th of that month reveals a single glochidium of what I am compelled to regard as this species. No development whatever is indicated and the presence of the glochidium at this late season may be due to some freak physiological characteristic not easily understood.

QUADRULA SOLIDA.

Two sunfish (*Lepomis pallidus*) were taken July 1, 1912, bearing glochidia of this mussel, one having 50 present, the other only 6. The development is similar to that noted in *plicata*, the foot and adductors being clearly indicated. The shell itself is not at all common in this region, and one would naturally expect to find few fish infected. The glochidium of this species closely resembles that of *ebena* and might be mistaken for the latter by a careless observer, but may be recognized by its greater comparative depth and shorter, straighter hinge line.

FIG-TOE (*Quadrula trigona*).

From the frequency with which this shell is found in the vicinity of Fairport, it is surprising more infected fish are not taken, its spawning season being July and August. So far only a single black crappie (*Pomoxis sparoides*) taken June 25, 1912, has been found infected, and it held but three glochidia, none of which showed any development whatever, thus indicating recent infection.

SUMMARY.

In conclusion attention is directed to the table of fish examined (table v), following. The remarkably small percentage of fish infected in a state of nature will be apparent at once, even of those species known to carry glochidia, if we except the skipjack (*Pomolobus chrysochloris*). In the case of the sheepshead, known to be the specific host for two species of mussels, the percentage is about $3\frac{1}{2}\%$, while in *Pomoxis annularis*, which carries more species of mussels than any other fish, it is only seven-tenths of 1 per cent. Out of a total of 38 species examined, numbering some 2,815 individuals, only 46 fish were infected, but of course only 11 species are apparently susceptible to natural infection. Further investigations will reveal much, the work having only begun. A summary of the present known hosts is shown in table vi.

By reference to table v the advantages of artificial infection can be readily imagined when the small percentage found infected in a state of nature is considered. Some one has long ago estimated that in the case of some fishes but 10 per cent of the eggs deposited naturally are even fertilized, whereas by artificial means it is now an established fact that fully 90 per cent, and even better, is not only possible, but a rule, in handling these same fishes. Now in the mussel the eggs are fertilized and the young developed ready for their parasitic life while still in the gills of the parent, so that all man has to do is find the specific host of a given species, procure that host, and load it to the limit, which may exceed the optimum infection of Lefevre and Curtis ^a in some cases. The simplicity of the proceeding is startling when we consider the ease with which the glochidia can be procured, a fair sized mucket (*L. ligamentina*), for instance, producing as many as 3,500,000 young and the niggerhead (*Q. ebena*) about 350,000.

TABLE V.—FISH CAUGHT AND EXAMINED FOR NATURAL INFECTION, JUNE TO NOVEMBER, 1912.

Species of fish.	June-July.		August.		September.		October.		November.		Total.	
	Exam-ined.	In-fected.	Exam-ined.	In-fected.	Exam-ined.	In-fected.	Exam-ined.	In-fected.	Exam-ined.	In-fected.	Exam-ined.	In-fected.
1. <i>Petromyzon castaneus</i>							1				1	
2. <i>Petromyzon concolor</i>			2		1		2				4	
3. <i>Polyodon spathula</i>			2				2				2	
4. <i>Scaphirhynchus platyrhynchus</i>			18		16		19	1	13	1	66	2
5. <i>Lepisosteus osseus</i>					7						7	
6. <i>Amia calva</i>			2		2						8	
7. <i>Ictalurus furcatus</i>					3						3	
8. <i>Ictalurus punctatus</i>			21		48		70		29		168	
9. <i>Ameiurus natalis</i>	6	1			2						8	1
10. <i>Ameiurus nebulosus</i>							1				1	
11. <i>Ameiurus melas</i>			4				2				6	
12. <i>Leptops olivaris</i>			44		18		4		1		67	
13. <i>Carpiodes carpio</i>							1				1	
14. <i>Carpiodes velifer</i>	18		7				3		13		41	
15. <i>Cydeptus elongatus</i>							2				2	
16. <i>Minytrema melanops</i>									1		1	
17. <i>Moxostoma breviceps</i>			1								1	
18. <i>Moxostoma aureolum</i>			3								3	
19. <i>Hiodon alosoides</i>					1						1	
20. <i>Pomolobus chrysocloris</i>			5	5	10	3					15	8
21. <i>Dorosoma cepedianum</i>					1				15		16	
22. <i>Esox vermiculatus</i>					1				1		2	
23. <i>Anguilla chrisypa</i>			1		2						3	
24. <i>Pomoxis sparoides</i>	7	1			104		144		3		258	1
25. <i>Pomoxis annularis</i>	30	5	195		640	1	278	3	12		1,155	9
26. <i>Ambloplites rupestris</i>							1		1		2	
27. <i>Apomotis cyanellus</i>	41	1	2		10		1		4		58	1
28. <i>Apomotis symmetricus</i>	1										1	
29. <i>Lepomis humilis</i>	42	1							1		43	1
30. <i>Lepomis pallidus</i>	35	4	30		137		43				245	4
31. <i>Eupomotis gibbosus</i>			3				1				4	
32. <i>Micropterus dolomieu</i>					3				1		4	
33. <i>Micropterus salmoides</i>			9		9		4				22	
34. <i>Stizostedion vitreum</i>							3		6		9	
35. <i>Stizostedion canadense</i>			5		20		32	1	38	2	95	3
36. <i>Roccus chrysops</i>			2		11	1	76		3		92	1
37. <i>Morone interrupta</i>			3		4				71		78	
38. <i>Aplocheilichthys grunniens</i>	30		141	6	27		104	5	20	4	322	15
Total.....	210	13	499	11	1,077	5	792	10	237	7	2,815	46

^a Lefevre, George, and Curtis, Winterton C.: Studies on the reproduction and artificial propagation of fresh-water mussels. Bulletin of the Bureau of Fisheries, vol. xxx, p. 159.

TABLE VI.—NATURAL HOSTS OF FRESH-WATER MUSSELS.

Species of fish.	Species of mussel and number of fish infected.												
	<i>Lampsilis anodonta</i> .	<i>Lampsilis fallax</i> .	<i>Lampsilis higinsoni</i> .	<i>Lampsilis laevis</i> .	<i>Lampsilis ligamentina</i> .	<i>Lampsilis recta</i> .	<i>Plagiola donachiformis</i> .	<i>Plagiola securis</i> .	<i>Pleurobema esopa</i> .	<i>Quadrula ebena</i> .	<i>Quadrula metanevra</i> .	<i>Quadrula plicata</i> .	<i>Quadrula pustulata</i> .
<i>Scaphirhynchus platyrhynchus</i>		2											
<i>Ameiurus natalis</i>													
<i>Pomolobus chrysochloris</i>										II			
<i>Pomoxis sparoides</i>	I												
<i>Pomoxis annularis</i>	2	I		2									
<i>Apomotis cyanellus</i>	I							I			I	I	I
<i>Lepomis pallidus</i>						I					5		
<i>Lepomis humilis</i>	I												
<i>Stizostedion canadense</i>			I				I	I	I			I	
<i>Roccus chrysops</i>					I								
<i>Aplodinotus grunniens</i>				10			9						

NOTE.—*Anodonta corpulenta* has been found but once, a young *Pomolobus chrysochloris* carrying a few on the fins; being an external parasite, it is not included in this table. *Ameiurus natalis* is included in the table because it was found to harbor one glochidium, the species of which was, however, indeterminable.

EXPLANATION OF PLATES.

PLATE XXIX.

FIG. 1. Glochidium of slop bucket, *Anodonta corpulenta*, on caudal fin of a young skipjack, *Pomolobus chrysochloris*.

FIG. 2. Young paper shell, *Lampsilis laevissima*, on gill of sheepshead, *Aplodinotus grunniens* (side view) in an early stage of development.

FIG. 3. Postero- or antero-ventral view of young *laevissima* of about the same development as figure 2.

FIG. 4-5. Another stage of development of *laevissima*, figure 4 representing side and figure 5 dorsal views.

FIG. 6-7. Side and dorsal aspects of *laevissima* upon reaching what is considered its greatest development as a parasite.

PLATE XXX.

FIG. 8. Postero-dorsal view of young deer-toe, *Plagiola donaciformis*, on gill of sheepshead, *Aplodinotus grunniens*.

FIG. 9. Side view of *donaciformis* on gills, the metamorphosis about completed.

FIG. 10. Portion of gill of *Aplodinotus* with young *donaciformis* in situ.

FIG. 11. Glochidium of niggerhead, *Q. ebena*, on gill filament of skipjack, *Pomolobus chrysochloris*, taken August 13.

FIG. 12. Dorsal and ventral views of *ebena* of same relative age as figure 11.

PLATE XXXI.

FIG. 13. *Quadrula ebena* presumed to have about completed its metamorphosis; a specimen taken September 23, 1912.

FIG. 14. Distal third of gill filament with glochidia of *ebena* in position.

FIG. 15. Glochidium of *Quadrula metanevra* on gill filament of sunfish, *Lepomis pallidus*.

FIG. 16. Glochidium of *Quadrula plicata* on gill filament of sauger, *Stizostedion canadense*.

FIG. 17. Glochidium of *Pleurobema æsopa* on gill filament of the sauger (*S. canadense*).

FIG. 18. Young *ebena* on gill filament, showing shifted position.

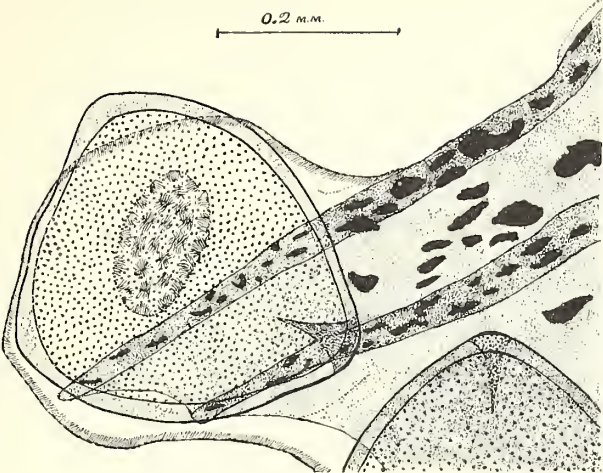


FIG. 1.

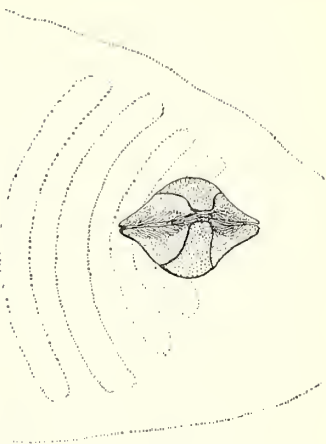


FIG. 5.

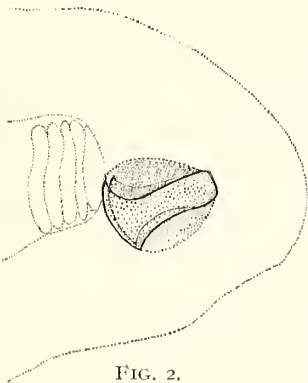


FIG. 2.

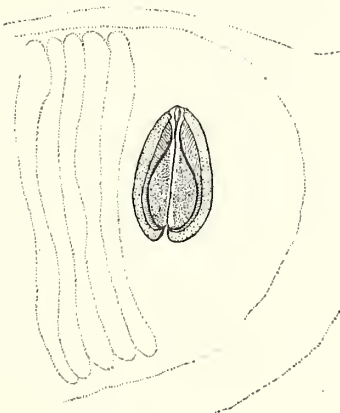


FIG. 3.

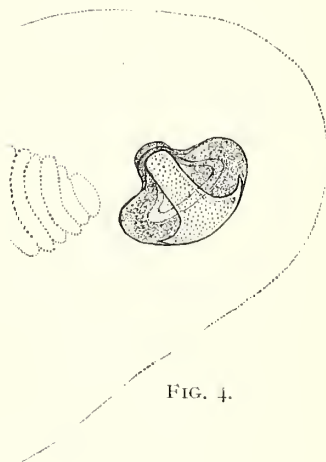


FIG. 4.

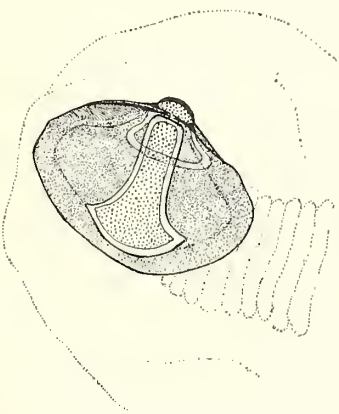


FIG. 6.

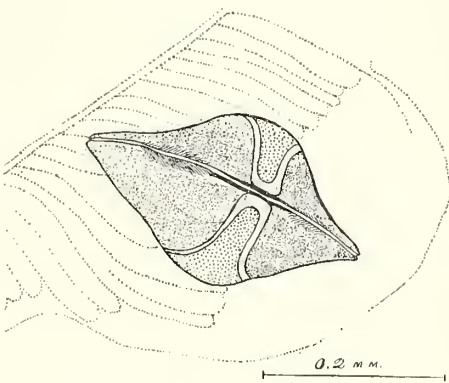


FIG. 7.

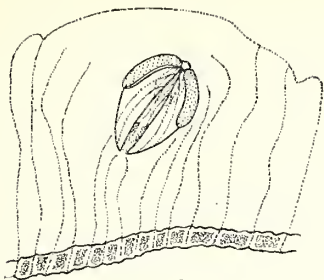


FIG. 8.

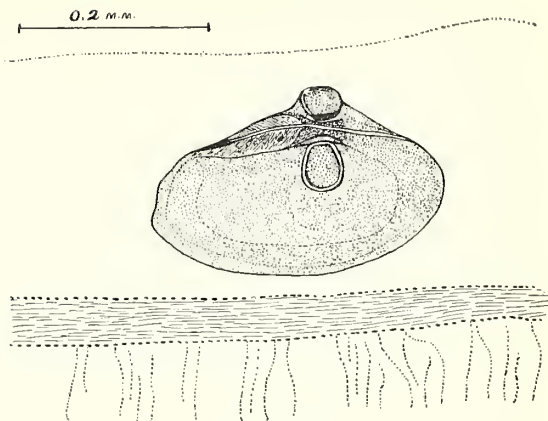


FIG. 9.

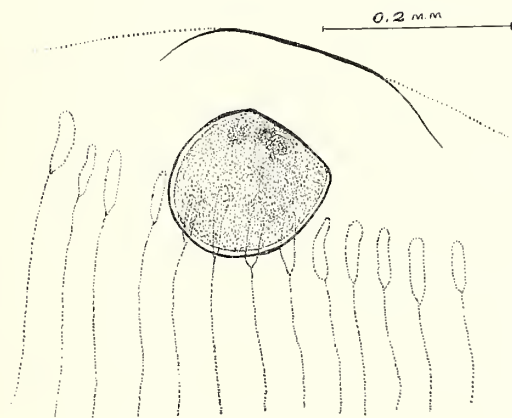


FIG. 11.

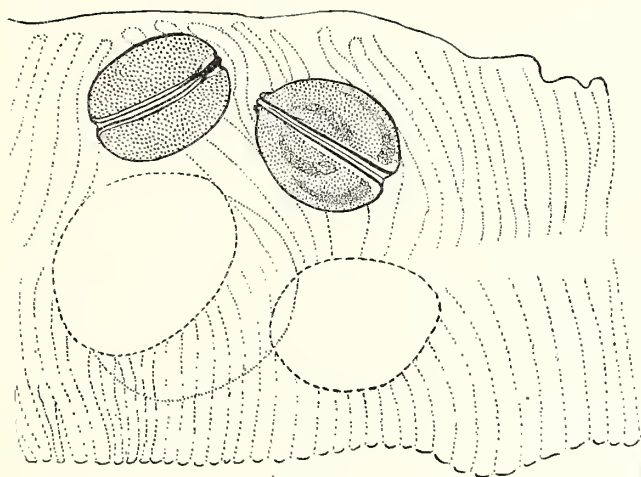


FIG. 12.

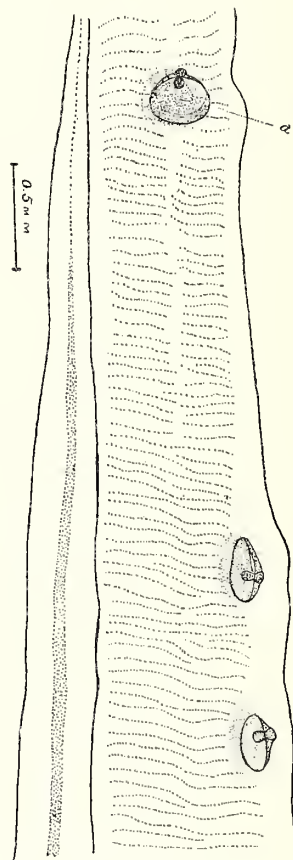


FIG. 10.

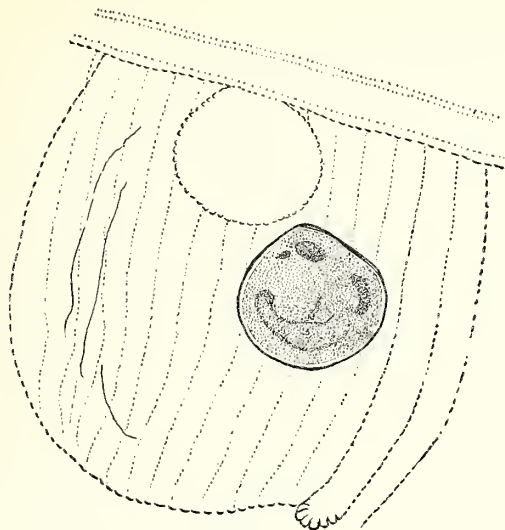


FIG. 13.

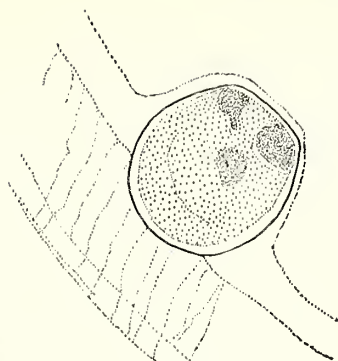


FIG. 15.

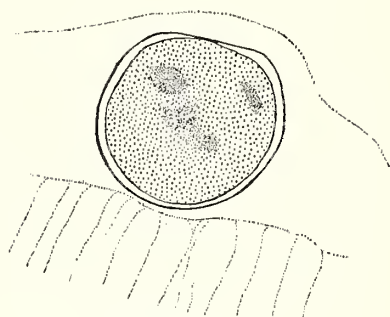


FIG. 17.

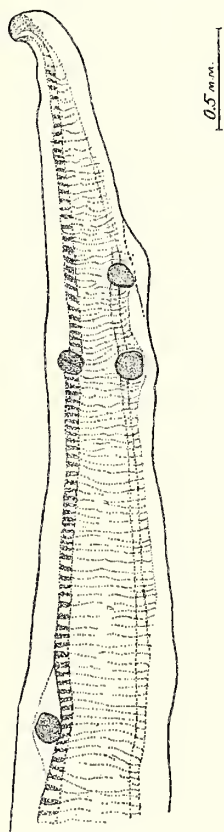


FIG. 14.

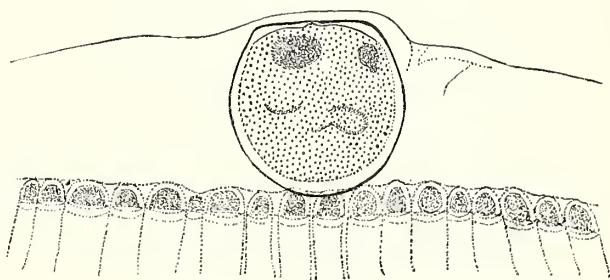


FIG. 16.

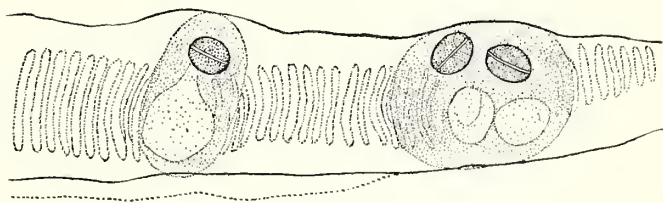


FIG. 18.

OBSERVATIONS ON FISH SCALES



By T. D. A. Cockerell

University of Colorado, Boulder, Colorado

OBSERVATIONS ON FISH SCALES.



By T. D. A. COCKERELL,
University of Colorado, Boulder, Colo.



INTRODUCTION,

In a paper on "The Scales of Freshwater Fishes" (Biological Bulletin of the Marine Biological Laboratory at Woods Hole, Mass., vol. xx, May, 1911) I have given an account of the recent work on teleostean fish scales and have discussed some of the problems presented by the scales of freshwater fishes. Until recently it has been impossible to do much with the scales of marine fishes, owing to the difficulty of obtaining adequate materials. For the same reason very little was done on the spiny-rayed freshwater groups, the Percidæ, Centrarchidæ, etc. During the summer of 1911, however, I was enabled to continue the work in the laboratory of the Bureau of Fisheries at Woods Hole, where the director, Dr. F. B. Sumner, afforded me every possible facility and put at my disposal a large series of fishes representing many families. I have also been very greatly indebted to the Bureau of Fisheries, through Dr. Hugh M. Smith and Dr. B. W. Evermann, for numerous and important specimens from the collections at Washington. At the National Museum Mr. B. A. Bean and Mr. A. C. Weed gave me much help and supplied scales of some important genera, while other very valuable materials were secured from the Museum of Comparative Zoology, through the kindness of Dr. S. Garman. As in former years, I have been indebted to Dr. Boulenger for some of the rarest forms. With all this the outlook has been greatly enlarged; but of course the results here reported are quite insignificant compared with those which will doubtless be attained, mainly by other workers, in the future. The whole subject is still in a preliminary stage, and when it is considered that the ideal program is no less than the examination and description of the scales of every scaly fish, with figures of all the genera, it becomes evident that there is work ahead for an indefinite number of years.

A few years ago an eminent European ichthyologist expressed the opinion that the detailed work on scales was a waste of time; for, said he, "We have other excellent characters on which to classify fishes, so why bother with scales?" Possibly this particular authority will never be converted to lepidology, but I do not believe anyone could spend much time in the minute study of scales without becoming convinced of their great value for purposes of identification and classification. Like all other structures, they vary, and present characters of all degrees of significance and stability; in

the earlier work we made some mistakes because of poor judgment in these matters. The correct estimation of the importance of particular scale characters can only come with experience, and if through lack of it some unsound opinions are expressed in this paper, the fact should not be used as an argument against the study of scales.

I have adopted, for the purposes of the present paper, the classification given by Dr. D. S. Jordan in his recent (1907) work "Fishes," pages 757-771. It is only necessary to compare the classification in recent standard works by Jordan, Boulenger, and Goodrich, together with the essays of Regan, to perceive that there is still latitude for much difference of opinion in regard to fish taxonomy. Neither the authors cited nor anyone else would pretend to be able to present a classification which is nearly perfect, although many important matters are generally regarded as settled. In the slow approximation toward a system based on real relationship, lepidologists venture to think that they may have a part, and the present essay is written largely with this end in view.

The cost of the photographs used to illustrate this paper has been defrayed by a grant from the American Association for the Advancement of Science.

Two corrections which I have had to make in this paper since it was written may be worth citing, as illustrating certain dangers of error, and at the same time bringing out clearly the general reliability of scales for identification.

Under *Boleosoma nigrum* I had written that the scales from Osterville, Mass. (from the collection at Wood's Hole), were so unlike those from Indiana that I supposed them to be wrongly determined. Dr. Sumner has since very kindly looked up the specimens, and reports that they are really *Boleichthys fusiformis*. In the case of *Carpiodes velifer*, I used scales from the fishes forming the basis of Juday's record for Boulder County, Colorado, without making any study of the fishes themselves. I noted with surprise that they corresponded "very well with the scales of the common goldfish." Dr. Max Ellis, going over the collection, has discovered that the specimens are in fact wild, dark-colored examples of the goldfish, *Carassius auratus*.

Class TELEOSTOMI. The true fishes.

Subclass CROSSOPTERYGII.

Order ACTINISTIA.

CÆLACANTHIDÆ (Fossil).

Dr. A. S. Woodward (Catalogue of Fossil Fishes, pt. 2, pl. xiv) has figured the scales of *Cælacanthus*. The figures are excellent, but unfortunately show only the apical (exposed) portion, which is ornamented with broad grooves running obliquely toward the middle line. Through the kindness of Dr. L. Hussakof, I have obtained the loan of several scales of *Cælacanthus robustus* Newberry, from the Carboniferous of Mazon Creek, Ill. These show that the scale is elongate in form, with a large basal region wholly free from grooves, and consisting entirely of very fine longitudinal fibrillæ, exactly as in *Amia*. The scales are about 12 mm. long and 8 broad.

There is a striking resemblance between the apical (exposed) area of *Cælacanthus*, with its grooved lines, and the same area in the South American characinid *Lebiasina bimaculata* Cuvier & Valenciennes.

Order CLADISTIA.

POLYPTERIDÆ.

The scales of *Polypterus endlicheri* Heckel from the White Nile (British Museum) are entirely of a dense bony consistence, the exposed surfaces rhombic or diamond-shaped with an enamel-like coating. The scales are produced into a long concealed process, and each has a peg or tooth fitting into a hole or socket in the next scale. Although *Polypterus* belongs to a very primitive group, its scales must be considered highly modified; the protection they afford may perhaps explain the survival of the genus. It is in *Cælacanthus*, not in *Polypterus*, that we get the real clue to the affinities of the crossopterygians.

Subclass DIPNEUSTI. Lungfishes.

Order CTENODIPTERINI.

CTENODONTIDÆ (Fossil). Comb-toothed Lung fishes.

The large scales of *Sagenodus* from the Carboniferous of Mazon Creek, Ill. (American Museum of Natural History), almost entirely agree with those of the living *Neoceratodus*. Aside from the irregular radii, forming a network in the central part of the scale, both form and structure are very near to those of the bowfin, *Amia*; and both, except for the lack of grooves in the exposed region, approach *Cælacanthus*. The one important feature in which all these agree is the large concealed area consisting of longitudinal fibrillæ. Among the Teleostei we find this retained only in the bonefishes, *Albulidæ*.

Order SIRENOIDEI. Sirenoid fishes.

CERATODONTIDÆ. Flatheads.

Neoceratodus forsteri, from Queensland (British Museum), has very large elongated scales with longitudinal beaded fibrillæ and a radial system of reticulation. (Science, May 26, 1911, p. 831.) The radial network and the tuberculate or beaded fibrillæ distinguish these scales from those of *Amia*.

LEPIDOSIRENIDÆ. Scaly sirenids.

The scales of *Lepidosiren* and *Protopterus* are briefly described in Science, May 26, 1911, page 831. Although these fishes come from widely separated regions (South America and Africa) and undoubtedly represent different subfamilies (*Lepidosireninæ* and *Protopterinæ*), their scales are almost exactly alike. There is a strongly developed radial network, as in the *Osteoglossidæ*, and the surface is minutely tuberculate, the tubercles derived from beaded fibrillæ. The scales are inclosed in the skin, and are circular or approximately so, not elongate as in *Neoceratodus* and *Sagenodus*.

Subclass ACTINOPTERI.

Superorder GANOIDEI.

In this case I prefer to write "superorder," rather than "series," as the term defines the rank of the category in relation to others.

Order GINGLYMODI.

LEPISOSTEIDÆ. Gar pikes.

The rhomboidal ganoid scales of the gar pikes *Lepisosteus* have a very close superficial resemblance to those of *Polypterus*, a case doubtless of convergence of type, due largely to the mechanical necessities of the situation. The scale of *Lepisosteus* is not so highly specialized as that of *Polypterus*, since it lacks the well-defined peg-and-socket arrangement. (For a further discussion of the scales of these genera, see Goodrich, Proceedings Zoological Society of London, November, 1907, p. 762-763.)

Order HALECOMORPHI.

AMIIDÆ. Bowfins.

I still write *Amia* and Amiidæ for the bowfin, being unconvinced that the rules of nomenclature require the change which has been proposed. The scale of *Amia* has been discussed in several of my earlier papers (e. g., Smithsonian Miscellaneous Collections, vol. 56, no. 1, p. 1). It has simple longitudinal fibrillæ, and no radial network. In its general structure it is not far from *Cælacanthus*, or indeed very remote from *Neoceratodus* and *Sagenodus*. No comparison is possible between the scales of *Amia* and *Lepisosteus*, and it is *Amia* alone which points toward the *Teleostei*.

Superorder TELEOSTEI. The bony fishes.

Order ISOPONDYLI. The isospondylous fishes.

I would change Jordan's arrangement of families to the extent of placing the Albulidæ first among the living groups, as undoubtedly the most primitive. It alone has the strictly longitudinal basal

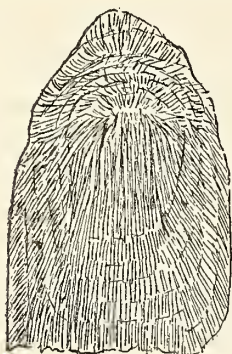


FIG. 1.—*Amia calva*.

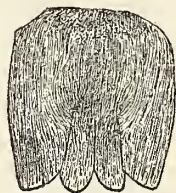


FIG. 2.—*Albula vulpes*
(Albulidæ). Bureau
of Fisheries.

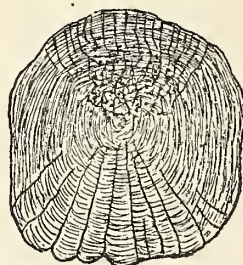


FIG. 3.—*Elops saurus* (Elopidae).
Bureau of Fisheries.

fibrillæ, which are tuberculate as in the Dipneusti. It alone, also, has two transverse series of valves to the bulbus arteriosus instead of one, another primitive character.

ALBULIDÆ. Bonefishes.

The scale of *Albula* is shown in text figure 2; that of *Dixonina* does not differ. In outline and general form these scales resemble those of *Synodus* and *Lucius* or *Esox* (pl. xxxv, fig. 19, 20), but these latter have transverse basal circuli.

ELOPIDÆ. Ten-pounders.

For a discussion of the scales of *Elops* see Smithsonian Miscellaneous Collections, volume 56, no. 3, page 3. Their structure shows nothing especially primitive; the basal circuli are very finely beaded, the lateral ones simple. The apical circuli, above the nucleus, break up into transverse labyrinthiform markings, the sculpture much coarser than that of the normal circuli.

MEGALOPIDÆ. Tarpons.

Jordan makes a separate family for the tarpons, although on an earlier page of the same book he follows the more usual custom of referring them to the Elopidae. I am indebted to Mr. V. N. Edwards for a scale of *Tarpon atlanticus* (Cuvier & Valenciennes), from Woods Hole, Mass. It is of course very large (62 mm. long, and almost as broad), and is formed much as in *Elops*, differing, however, by having only three basal radii (12 to 20 in *Elops*), the basal margin broadly scalloped much as in *Synodus*. The

scale is indeed curiously similar in form and structure to that of *Synodus*, though the nucleus is not so far apicad. The region above the nucleus is minutely roughened or tuberculate, and the apical circuli are longitudinal. The basal circuli are finely beaded.

HODONTIDÆ. Toothed herrings.

The scales of the moon-eye *Hiodon tergisus* are discussed in Smithsonian Miscellaneous Collections, volume 56, no. 3, page 3. They have much in common with *Elops*, but the wholly transverse fine circuli of the apical field are not at all modified above the nucleus. The basal radii are numerous and irregular, inclined to be divided into two groups, and the basal margin is undulate, not scalloped. The basal circuli are without distinct beading. The scale is of a cyprinoid type.

CHIROCENTRIDÆ. Long herrings.

The long herring, or dorab, *Chirocentrus dorab* (Forskål), from the Philippine Islands, has transverse circuli and radii, essentially as in Clupeidæ, the radii usually angled in the middle. There are also irregular basal longitudinal radii, few in number, much as in the anchovy *Stolephorus argyrophanus*. On page 113 of volume XXIII of the Proceedings of the Biological Society, Washington, for "five transverse circuli" read "fine transverse circuli," and it is the basal, not the apical field, which has these more widely spaced circuli. Upon minute comparison I find that the whole arrangement, both circuli and radii, agrees essentially with *Stolephorus argyrophanus*, and hence in its scales *Chirocentrus* is to be compared with the Engraulidæ rather than with the Clupeidæ. The scale is, in fact, wholly as in the engraulids.

ENGRAULIDIDÆ. Anchovies.

I alter Jordan's arrangement by placing these before the Clupeidæ, as being more primitive, at least as to the scales, and also nearer the chirocentrids. Dr. Max Ellis has prepared a paper fully discussing the available material. Some of the species show an evident reticular network, in one case so well developed that the scale looks like that of some osteoglossid.

CLUPEIDÆ. Herrings.

I here consider only the Clupeinæ, of which I have examined nearly all the American genera. Two tribes are indicated, Brevoortini, for *Brevoortia*, and Clupeini, for the other genera. In the menhaden, *Brevoortia tyrannus* (Latrobe), the apical margin of the scale is produced into long parallel teeth with very slender ends. These teeth arise from a pellucid apical zone, and the intervals between them are prolonged basad as grooves for a distance about equal to the length of the teeth. Below these grooves are numerous small and short grooves looking like roots, the large grooves seeming to be the stems from which they arise. Below this the scale is entirely covered with very fine transverse circuli, and has in addition irregular pits and two transverse radii. The dentate scale margin is by no means peculiar to *Brevoortia*; it is quite distinct, for example in *Alosa* and *Clupea*, but the teeth are very irregular and by no means so long or tapering. In juvenile *Alosa* the margin is not dentate. The pitting seen in *Brevoortia* is also very strongly developed in some scales of the thread herring, *Opisthonema oglinum* (Le Sueur), from Woods Hole; it is evidently derived from evanescent transverse radii. In some scales of *O. oglinum* there are five transverse radii, all but the uppermost broken in the middle; there is then no pitting, but the well-pitted scales have only the upper radius. In the pilchard, *Clupanodon pilchardus*, from Palermo, Italy (Bureau of Fisheries), there are seven or eight transverse radii, all widely broken in the middle except the first, the lower ones oblique, the whole reminding one of the ribs of the human skeleton seen from in front. The extremely fine circuli are strictly transverse, meeting the lateral margins at right angles. I find essentially the same in the West Indian sardine, *Clupanodon pseudohispanicus* Poey, from Woods Hole (pl. xxxv, fig. 18), but in two scales I notice that the circuli curve upward on one side only.

Comparing *Clupanodon* with the sea herring, *Clupea harengus* (from Woods Hole and Sandy Island), two differences are at once apparent. In *Clupea* the transverse radii are commonly (though not uniformly) entire, or not interrupted in the middle, whereas in *Clupanodon* they are (except the first)

quite regularly interrupted; in *Clupea* also it is common to find a pair of irregular apical radii, joining basally to form a sort of U. In *Clupea* the lateral circuli, following the trend of the transverse radii, reach the margin obliquely, not at right angles as in *Clupanodon*; this seems to be in some degree a matter of age, yet the large scales from Woods Hole, in which the obliquity of the circuli is very strongly marked, show growth lines delimiting various younger stages, and when less than half grown the circuli were already moderately oblique. It is a curious thing that the scales from Sandy Island (Bureau of Fisheries) have the transverse radii more numerous, much less regular, and interrupted at intervals, the circuli more transverse, in the young very little oblique, and the lower limit of the hyaline apical area straight or almost, whereas in the Woods Hole scales it is concave or even broad V-shaped. Are there two types of herrings, or is this individual variation?

The large scale of the shad, *Alosa sapidissima*, has been figured in Smithsonian Miscellaneous Collections, volume LVI, no. 1, page 2, and discussed at length in the Proceedings of the Biological Society of Washington, volume XXIII, pages 61-62. It is shown that the transverse radii are derived from the apical radial system, all stages of transition being visible. The adult *Alosa* scale has the circuli and radii at the sides very oblique; in some scales the radial system is very highly developed, with very numerous apical radii, and those about the middle of the scale variously anastomosing, forming an irregular network. There is, however, no approach to the type of network seen in some *Engraulididae* and better developed in *Osteoglossidae*. So far as the scale goes, *Alosa* must stand at the base of

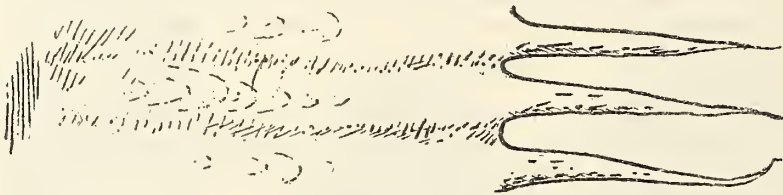


FIG. 4.—*Brevoortia tyrannus* (Clupeidae). Apical teeth. Bureau of Fisheries.

the clupeine series, with *Clupea* close to it but a little more advanced. *Clupanodon* then represents a considerable further step in the direction of clupeine specialization, with the fixation of the more characteristic features.

In *Sardinella humeralis* (Cuvier & Valenciennes), from Tampa, Fla., the scales differ conspicuously from *Clupea*, *Clupanodon*, *Alosa*, etc., in being much broader than long, the lower corners obtusely almost rectangular. The circuli are strictly transverse, not oblique; there are two widely separated entire transverse radii, and part of a third one forming a small reversed broad V on the lower margin; the lower margin of the hyaline area is slightly concave. These scales are perhaps not adult; they resemble in many ways the immature scales of *Alosa*.

The scales of the alewives, *Pomolobus*, have the lateral circuli moderately oblique, except in the young; the undulating transverse radii distinctly rather widely spaced, often broken in the middle but not regularly or widely so, as in *Clupanodon*. Two species before me are rather easily distinguished:

Pomolobus æstivalis (Mitchill). Glut herring. Scales about as long as broad; lower margin of hyaline area concave.

Pomolobus pseudoharengus (Wilson). Branch herring. Scales conspicuously broader than long; lower margin of hyaline area straight. In a former paper I said I did not know how to distinguish young scales of *P. pseudoharengus* from young of *Alosa sapidissima*. However, in the *Alosa* the lower margin of the hyaline area is uniformly distinctly concave; in *P. pseudoharengus* it is straight or even convex, except in the very earliest stage, when the diameter is much less than a millimeter. Reviewing the Clupeinæ, it appears that we may place *Alosa* at the base of the series, and just above it *Clupea*. Then *Clupanodon* stands at the end of a branch, from the side of which springs *Opisthonema*, leading directly toward *Brevoortia*. From an earlier part of the same branch may arise *Pomolobus*, and somewhere near here *Sardinella*. All this is based on the scales, and must of course be modified when the structures are considered.

The character given in Jordan and Evermann's key for all the clupeines except *Brevoortia*, "scales with their posterior [apical] margins entire and rounded" is not accurate, although *Brevoortia* scales are readily separated from the others by their long weak teeth.

PHRACTOLÆMIDÆ.

Phractolæmus is a living African fresh-water genus; Jordan has the family printed by error in italics, as extinct. The scales of the only known species are described in the Proceedings of the Biological Society of Washington, volume XXIII, page 112, and figured in Biological Bulletin, volume XX, plate III, figure 17a. They strongly suggest certain of the Characinidæ.

OSTEOGLOSSIDÆ. Bony-tongued fishes.

There are at least two subfamilies, Osteoglossinæ (*Osteoglossum* and *Scleropages*) and Heterotinæ (*Heterotis*). The scales of this group, remarkable for their regular network and beaded circuli (primitive characters recalling the Dipneusti), have been discussed in the Proceedings of the Biological Society of Washington, volume XXIII, page 111, and volume XXIV, page 39; Science, May 26, 1911, page 831; and *Heterotis* is figured in Biological Bulletin, volume XX, plate III, figure 20. Mr. W. M. Mann has kindly sent me scales of the Amazon bone-tongue, *Arapaima gigas* (Cuvier), which Eigenmann makes the type of a distinct family, *Arapaimidæ*. They are about 78 mm. long and 55 broad, superficially like those of *Neoceratodus*. The exposed part has a very coarse labyrinthoid rugosity. The concealed part has elongated reticulations and beaded circuli; the reticulation very irregular and not nearly so well developed as in *Osteoglossum*. The scale is really very near to that of the Nile bone-tongue, *Heterotis*.

PANTODONTIDÆ. Pantodonts.

Living African fishes, only one species known. The scales are described in the Proceedings of the Biological Society of Washington, volume XXIII, page 112, and figured in Biological Bulletin, volume XX, plate III, figure 18. The circuli are strongly beaded.

NOTOPTERIDÆ. Finbacks.

Fresh-water fishes of the Ethiopian and oriental regions, considered by Boulenger to be nearest to the Hiodontidæ. The scales of the African *Notopterus afer* Günther are described in the Proceedings of the Biological Society of Washington, volume XXIII, page 112. In this place I have remarked on the resemblance of the scales to those of *Gadus*. This is certainly true as regards shape and general appearance, but on close comparison it is seen to be wholly superficial. In the gadines the numerous fine radii extend in all directions from the nucleus; in *Notopterus*, except for a series of striæ just below the apical margin, they are wholly basal, and only the central ones reach the nuclear region. In *Notopterus* these radii are only about half as dense (close) as in *Gadus*, but on the other hand the circuli are much denser. The circuli of *Notopterus* are not at all beaded.

SALMONIDÆ. Salmon, trout, etc.

Very good figures of *Salmo* scales have been published by Mr. J. Arthur Hutton in his pamphlet on "Salmon Scale Examination and its Practical Utility" (London, 1910). He shows that the life of the fish affects the growth of the scales, so that by examining the scales it is possible to determine the approximate age, the time spent in the river and in the sea, and other important facts. The salmonoid scales before me are the Atlantic Salmon, *Salmo salar* Linnæus, Woods Hole, Mass.; the golden trout, *S. roosevelti* Evermann, cotype, Mount Whitney, Cal.; Coulter's whitefish, *Coregonus coulterii* Eigenmann & Eigenmann, cotype, Kicking Horse River, Field, British Columbia; the brook trout, *Salvelinus fontinalis* (Mitchill), Woods Hole, Mass.; the blueback or red salmon, *Oncorhynchus nerka* (Walbaum), Wallowa Lake, Oreg. (J. J. Stanley). I have figured the scale of the blackfin, *Leucichthys nigripinnis* (*Argyrosomus nigripinnis* Gill), in Biological Bulletin, volume XX, (1911), plate I, figure 2. The scales of *Salmo* are more or less oval, with well developed concentric circuli, which variously fail in the apical region; the radii are absent. Scales of *Salvelinus* and *Oncorhynchus* are essentially the same; with

the material before me I am not able to make any satisfactory table for their separation. *Leucichthys nigripinnis* is distinct by the evident laterobasal angles. *Coregonus couleri* scales are about 1.5 mm. long by 2 broad, varying to approximately circular, but apparently never (at least on the middle of the side of the fish) longer than broad, as is usual in the *Salmo* group. The circuli are very widely spaced, and there are rather obscure indications of laterobasal angles. These *Coregonus* scales are perhaps immature. It is probable that the following characters are valid for the subfamilies:

COREGONINÆ, WHITEFISHES AND LAKE HERRING.—Scales as broad or broader than long, with laterobasal angles more or less developed.

SALMONINÆ, SALMON, TROUT, ETC.—Scales nearly always longer than broad, without laterobasal angles. Of these, the Coregoninæ must apparently be considered the more primitive.

ARGENTINIDÆ. Smelts.

Osmerus mordax Mitchell, from Menemsha Bight, Mass. (J. T. Field), has approximately circular scales about 2.5 mm. diameter, without radii. The circuli are very widely spaced except basally, where they are crowded; they are obtusely angled in the middle line above and on each side. The laterobasal corners are very obtuse but evident; the basal middle is broadly produced into a rounded lobe, which is usually emarginate. The nucleus is far toward the base of the scale, approximately on a level with the laterobasal corners.

This scale is in general related to that of the Coregoninæ, but is readily distinguished by the position of the nucleus.

SYNODONTIDÆ. Lizard-fishes.

Rather large semicircular cycloid scales; nucleus a little (*Trachinocephalus*) or considerably (*Synodus*) above the middle; very strong basal plicæ (2 or 3 in *Trachinocephalus*, 3 or 4 in *Synodus*); circuli normal, quite dense in *Synodus*, rather widely spaced in *Trachinocephalus*, the apical ones longitudinal; laterobasal angles evident but obtuse; apical marginal area broadly thin and sculptureless, in the manner of certain clupeids, but the submarginal area, or marginal area of the scale proper, sculptureless, except for scattered punctiform markings, its margin irregularly minutely dentate (more evidently in the *Synodus*), as if very irregularly broken. Scales of *Synodus* yellowish, of *Trachinocephalus* colorless.

The species studied are *Trachinocephalus myops* (Forster), the ground spearing, from Woods Hole, Mass., and *Synodus fætens* Linnæus, the lizard fish (pl. xxxv, fig. 19), from Galveston, Tex. (Evermann). The apical structure seems to be prophetic of the acanthopterygian type of ctenoid scale; in the Gerridæ (*Xystæma cinereum* Walbaum) the apical margin is very thin, covered with minute shadowy diamond-shaped markings, the vestiges of the disappearing teeth; no such vestiges can be seen in the Synodontidæ, although the superficial appearance is similar. Jordan notes of Synodontidæ that the head is scaly, "a character rare among the soft rayed fishes," but usual among Acanthopterygians.

MAUROLICIDÆ.

Maurolicus pennanti (Walbaum), from Woods Hole, Mass., has easily deciduous, extremely thin scales, with widely spaced evanescent circuli. According to Jordan, the Maurolicidæ are scaleless, but no doubt the specimens examined had lost their scales. Dr. F. B. Sumner tells me that he carefully worked over the Woods Hole species and noted the presence of scales.

In the related family of Myctophidæ, the lantern fishes, the scales of *Myctophum resplendens*, as figured by Günther, are better developed; broad, cycloid, regularly circulate, nucleus nearly central, about six strong basal folds. They are rather like those of *Cypsilurus*.

Order APODES. Apodal fishes.

Suborder ENCHELYCEPHALI. The eels.

ANGUILLIDÆ. Fresh-water eels.

The scale of the common eel (*Anguilla rostrata* or *chrisypa*) is a remarkable structure, very unlike any of the scales discussed above. It is 2 mm. long, or slightly over, narrow, and with rounded ends, approximately sausage-shaped in outline. The nucleus is central, and on an extremely fine reticulated

framework are arranged concentric rings of oval elements, which are hyaline with narrow dense margins. These oval bodies are actually capable of being detached, or more strictly speaking their surface layers are detachable, retaining their original form and appearance.

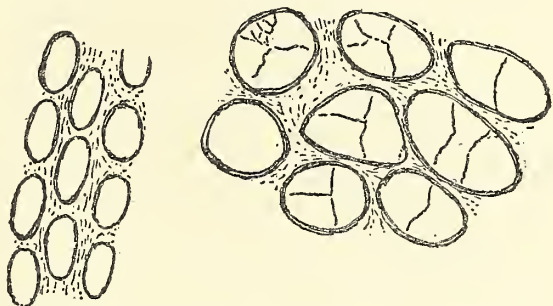


FIG. 5.—*Anguilla rostrata* (Anguillidæ). Details of sculpture. Bureau of Fisheries.

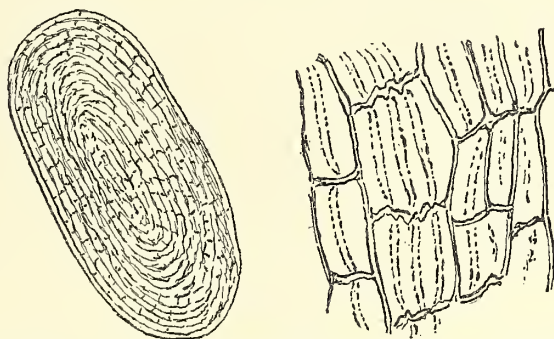


FIG. 6.—*Synphobranchus pinnatus* (Synphobranchidæ). Bureau of Fisheries.

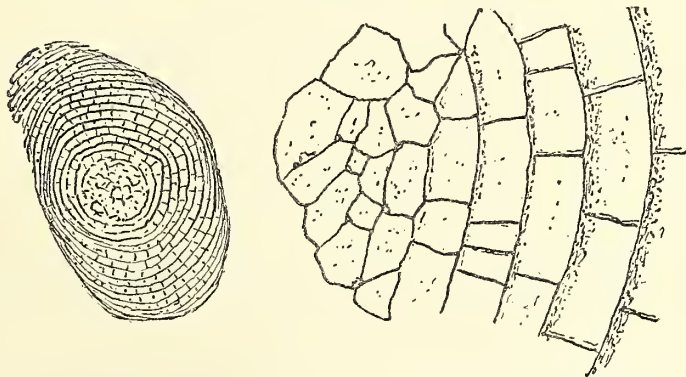


FIG. 7.—*Ichthyophis glutinosus* (Cæciliidæ). Amphibian scale. British Museum.

SYNAPHOBRANCHIDÆ.

In *Synphobranchus pinnatus* (Gronovius), a deep-sea eel, the scales are shaped much as an *Anguilla*, but not so elongate, and very much smaller, the length about two-thirds of a millimeter. The general appearance and detailed structure are shown in the figure. In this scale we get a clue to the evolution

of the *Anguilla* type, the structure, with its upper and lower layers, being much the same; but the upper layer exhibits more or less quadrangular spaces, due to the crossing of the radial and circular systems. The specialization of detachable oval plates does not exist, but it is possible to see how it might arise from a type resembling *Synaphobranchus*.

Although I have found nothing among the primitive fishes which seemed to lead toward the eels, there is a distinct resemblance, I believe not altogether superficial, to be observed in the scales of the cæciliid amphibians. I am greatly indebted to Dr. Boulenger for material of *Ichthyophis glutinosus* (see text fig. 7). Here the elongate quadrangular spaces are arranged like bricks in a wall, but in concentric circles, while the center of the scale is reticulate and minutely tuberculate, quite closely simulating the condition in the Lepidosirenidæ. Thus in a remote and general way, *Ichthyophis* scales connect those of the eels with those of primitive fishes, suggesting that the eel type is really a very ancient one, not derived from any of the groups of fishes nearly associated with it in the classification.

In this connection the extinct Archencheli, considered primitive eels with isospondylous traits, become very important. I have never seen *Urenchelys*, but Dr. A. S. Woodward says of it, "scales rudimentary"; and under *U. avus* A. S. Woodward, he says of one specimen, "there are no traces of scales," but of another, "the brownish impression of the soft parts of the fish is curiously mottled, as if there were indications of small, rudimentary quadrangular scales." Looking in the opposite direction, we find an unexpected revival of the ichthyophoid type of scale, at least as regards the quadrangular areas, in the gadid *Brosmius brosme*, the cusk. The fine radii are broken so that, as in *Ichthyophis*, the bricklike spaces are largely laid in alternate fashion, not one directly above the other. In the pollocks, *Pollachius* and other genera, however, the radii are essentially continuous, and one can hardly doubt that the *Brosmius* scale was derived from a *Pollachius*-like type. In this connection it is worth while to note that *Sphyræna picuda* has a scale pattern practically identical with that of *Pollachius*.

All things considered, it must be admitted that the eel type of scale could have been derived from something of the *Sphyræna* or gadid pattern, and hence it is not necessarily primitive. The resemblances noted are, however, interesting, and may not be without some significance.

According to Boulenger, the scales of the Murænolepididæ resemble those of the Anguillidæ.

Order OSTARIOPHYSI.

Suborder HETEROGNATHI.

CHARACIDÆ (CHARACINIDÆ). Characins.

The scales of the African species have been discussed in Smithsonian Miscellaneous Collections, volume 56, no. 1. Those of the South American genera form the subject of a lengthy paper to be published by the Carnegie Museum. This also includes the Erythrinidæ.

Suborder EVENTOGNATHI.

CYPRINIDÆ. Minnows and carps.

The scales of this family have been discussed in numerous papers. I give here a list of the genera which I have examined, with references to literature and some additional information and figures.

(A) AMERICAN GENERA.

It is doubtful whether any genera of Cyprinidæ are common to America and the Old World, except, of course, those introduced by man.

Abramis auctt. Amer., the shiner=*Notemigonus*.

Acrocheilus Agassiz, the chisel-mouth. Proc. Biol. Soc. Wash., XXII, p. 210 (subfamily Chondrostominae).

- Agosia* Girard, the western dace. Proc. Biol. Soc. Wash., xxii, p. 157. Girard, Ichthyology of the Mexican Boundary Survey, pl. xxvii, fig. 6-8 (*notabilis*=*oscula*); pl. xxvii, fig. 10-12 (*oscula*); pl. xxviii, fig. 6-8 (*chrysogaster*); pl. xxviii, fig. 2-4 (*metallica*-*chrysogaster*). Girard's figures show that the scales of the subgenera *Apocope* and *Agosia* are essentially of the same type, more or less elongate, with basal as well as apical radii. According to the figures, the scales of *A. chrysogaster* are distinctly different from those of *A. metallica*, the former rounded, the latter quadrate. Is it not probable that there are two species or races?
- Algansea* Girard. (Pl. xxxii, fig. 3.) Proc. Biol. Soc. Wash., xxiv, p. 213 (*A. sallæi*); Zoologischer Anzeiger, xxxvi, p. 476 (*tincella*); Biological Bulletin, xx, p. 373 (*tincella*, *affinis*, *stigmatura*). Girard figures the scales in Ichthyology of the Mexican Boundary Survey, pl. xxvii, fig. 2-4. They are of the same general type as those of *Agosia*, longer than broad, with basal as well as apical radii. According to the scales, *Algansea* does not seem near to *Hybognathus* (the scales of which are large and broad, without basal radii), but should be an herbivorous representative of the *Agosia*-*Rhinichthys* group, or related in some way to *Temeculina*. Among the herbivorous groups, it is by its scales nearer to the Chondrostominae and Chrosominae than to the Pimephalinae. May we not regard it as a modified chondrostomine, pointing somewhat in the direction of the *Agosia* group? In any case the scale characters must be considered relatively primitive and indicative of affinity with Old World types.
- Campostoma* Agassiz, the stone-roller. Proc. Biol. Soc. Wash., xxii, p. 122. Girard, Ichth. Mex. Boundary Survey, pl. xxv, figures scales of *C. ornatum*, *anomalum* (as *nasutum*) and *formosulum*; they are all broad, with nucleus far basad of the middle, and apical radii only; the general type of *Notropis* and many other American genera. This genus is the type of a distinct subfamily, peculiar to America.
- Chrosomus* Rafinesque, red-bellied dace. Biol. Bulletin, xx, p. 370, pl. 1, fig. 5; Proc. Biol. Soc. Wash., xxii, p. 121. Scale broader than long, with radii all around; the type that of the European *Phoxinus*. An isolated genus in America.
- Cliola* Girard. Proc. Biol. Soc. Wash., xxii, p. 189 (*C. smithii*). Girard, Ichth. Mex. Boundary Survey, pl. xxxi, fig. 22-24 (*velox*=*vigilax*). The scales are broad, with about 19 apical radii in *C. smithii*, about 8 or 9 (according to Girard's figures) in *vigilax*. The genus seems to stand between *Pimephales* and *Notropis*.
- Cochlognathus* Baird & Girard. Girard, Ichth. Mex. Boundary Survey, pl. xxxv, fig. 15-17, shows very broad scales with subbasal nucleus, the radii only apical, about 10 or 12, not nearly reaching the nucleus. According to the figures the basal margin is strongly convex, not straight as shown in *Cliola vigilax*. Thus the base of the scale is practically as in *Lavinia*, while that of *C. vigilax* may be compared with *Ericymba* or *Phenacobius*.
- Couesius* Jordan, the chub-minnow. Proc. Biol. Soc. Wash., xxii, p. 159. Near to *Semotilus*; apical circuli angulate in the middle.
- Ericymba* Cope. Proc. Biol. Soc. Wash., xxii, p. 162, pl. iii, fig. 1; Biological Bulletin, xx, p. 374, pl. v, fig. 28 (normal scale) and fig. 29 (latinnucleate scale).
- Exoglossum* Rafinesque, the cut-lip. Proc. Biol. Soc. Wash., xxiv, p. 213. Scale resembling that of *Mylocheilus*.
- Gila* Baird & Girard, the bony-tail. Biological Bulletin, xx, p. 374, pl. v, fig. 30 (scale of young *G. robusta*); Girard, Ichth. Mex. Boundary Surv., pl. xxiv, fig. 10-12 (*grahami*=*robusta*); pl. xxxiii, fig. 8-10 (*emorii*=*elegans*). The mature scale is more or less elongate, with a distinct basal lobe, the base being in general like that of the shorter scale of *Lavinia*. A *Gila* about 9½ inches long, collected by Messrs. E. R. Warren and J. W. Frey in the Bear River at Lily, Routt County, Colo., June 30, 1909, appears to be *G. seminuda* Cope & Yarrow. The caudal peduncle is almost 13 mm. in depth, the base of the caudal fin 20 mm. The fish is a typical *Gila*, and *G. seminuda* appears to have been based on an immature specimen. The ventral surface is without scales. Peritoneum rather dilute black, not spotted. Posterior division of air bladder large and broad, its breadth 16 mm. Scales in lateral line about 96; the scales are elongate, with parallel, even concave sides;

laterobasal corners prominent though rounded; basal lobe very large; *Gila* seems to be a very good genus, a fact of some importance, since if it were united to *Richardsonius*, the name *Gila* would have priority.

Hybognathus Agassiz, silvery minnow. Proc. Biol. Soc. Wash., xxii, p. 122. Girard, Ichth. Mex. Boundary Survey, pl. xxvi, fig. 10-12 (*H. serena*); pl. xxvi, fig. 14-16 (*chrysitis=serena*); pl. xxvi, fig. 22-24 (*texasensis=episcopa*); pl. xxvi, fig. 6-8 (*argentosa=?episcopa*); pl. xxvi, fig. 18-20 (*melanops*); pl. xxvi, fig. 2-4 (*couchi=melanops*); pl. xxvii, fig. 18-20 (*amara*); pl. xxvii, fig. 14-16 (*fluviatilis=amara*). A member of the Pimephalinae, with scales of the type of *Notropis*, etc.

Hybopsis Agassiz, horny-head. Proc. Biol. Soc. Wash., xxii, p. 162 (species of *Hybopsis* s. str., and the subgenera *Erimystax* Jordan, *Yuriria* Jordan & Evermann, and *Macrhybopsis* Cockerell & Allison).

Girard, Ichth. Mex. Boundary Survey, p. 50, briefly describes the scales of *H. æstivalis* (Girard).

Lavinia Girard. Proc. Biol. Soc. Wash., xxii, p. 161; Biological Bulletin, xx, pl. iv, fig. 23.

Lepidomeda Cope. Proc. Biol. Soc. Wash., xxiv, p. 213. Scales transversely oval.

Leuciscus auctt. Amer., dace=*Richardsonius*.

Mylocheilus Agassiz, Columbia chub. Proc. Biol. Soc. Wash., xxiv, p. 213. The species there called *M. caurinus* (Richardson) is *M. lateralis* Agassiz & Pickering, *caurinus* auctt., not of Richardson. The species of Richardson is to be called *Richardsonius caurinus*. *Mylocheilus lateralis* often enters the sea.

Myloleucus Cope. Proc. Biol. Soc. Wash., xxii, p. 161 (as *Rutilus*); xxii, p. 217. The aggregate called *M. symmetricus* is discussed in Biological Bulletin, xx, p. 374.

Mylopharodon Ayres. The scales of immature *M. conocephalus* (Baird & Girard) from Merced River, California, are broad-oval, and except that they are considerably broader in proportion to their length, closely resemble in form and structure those of *Orthodon microlepidotus*; the pattern, with few (about 8) radii, all apical and widely spaced, and the interradii circuli very widely spaced, is exactly as in *Orthodon*. The base is broadly rounded, and there are no laterobasal angles. The fish has a large forked caudal; scales small; gill lamellæ very obtuse; peritoneum marbled with light brown and speckled with black. Jordan & Evermann place this genus, with *Mylocheilus* and *Stypodon*, in a subfamily Mylopharodontinae, said to contain comparatively primitive forms, allied to those of Asia. The scales of *Mylocheilus lateralis* differ conspicuously from those of *Mylopharodon*, having the apical radii quite three times as numerous, and the sides nearly straight, with obtuse but evident laterobasal angles, the basal margin strongly convex in outline. Except for the absence of basal radii, they very greatly resemble the scales of *Chondrostoma*. It seems probable that Mylopharodontinae should be regarded as a tribe only (*Mylopharodontini*) of Chondrostominae.

Nocomis Girard. Proc. Biol. Soc. Wash., xxii, p. 161-162. The scale is formed and sculptured much after the manner of that of *Richardsonius (Tigoma) pulchellus*, but is much broader, with the vertical sides considerably shorter. (Pl. xxxii, fig. 6.)

Notemigonus Rafinesque, shiners. Proc. Biol. Soc. Wash., xxii, p. 211-213. Girard, Ichth. Mex. Boundary Survey, pl. xix, fig. 10-12 (as *Luxilus leptosomus*). On the same fish (from Falmouth, Mass.) the apical radii vary from 4 to 9; there are no traces of basal radii. The scales of *N. chrysoleucas* (pl. xxxiii, fig. 8), first seen by me were immature; obtaining mature scales, I find that they are almost identical in form and sculpture with those of the European *Abramis elongatus* Agassiz, both being extremely different from those of *A. brama*, the type of *Abramis*. According to the scales, *Ballerus* should be much nearer to *Notemigonus* than to *Abramis*. *Ballerus* is, however, separable from *Notemigonus* by the teeth and fins.

Notropis Rafinesque, minnows. Proc. Biol. Soc. Wash., xxii, p. 189-196; Biol. Bulletin, xx, pl. iv, fig. 25 (*galacturus*); Proc. Biol. Soc. Wash., xxii, p. 158, fig. 3 (*cornutus*); Girard, Ichth. Mex. Boundary Survey, figures *N. lutrensis (complanata)*, *couchi*, *gibbosa*, *rutilla*, *proserpina (aurata)*, *macrostomus* (including *luxiloides*), *texasus*, *venustus*, *swaini (megalops)*, *amabilis*, *socius*, *frigidus*, *formosus*, *ornatus*, and *aztecus (vittata)*. Girard figures the scales of the two subgenera (*Aztecula* Jordan & Evermann and *Codoma* Girard) not studied by Cockerell & Calloway in 1909. *Aztecula*

(*N. aztecus*) has scales which are narrower than those of most *Notropis*, with about 9 to 11 apical radii. *Codoma* (*N. ornatus*), a fish remarkable for its vertical dark bands, has very ordinary scales of the *Notropis* type, the apical radii 9 or 10. The subgeneric name *Coccogenia* Cockerell & Calloway gives way to the earlier and long-forgotten *Coccolis* Jordan, as Fowler has pointed out. Two new descriptions are added:

Notropis lermæ Evermann & Goldsborough. Cotype; Lake Lerma, Mexico (J. N. Rose). Scales about 1.5 mm. long and 1.75 broad, rounded, not at all triangular, with 18-21 apical radii.

Notropis horatii Cockerell. Type; Julesburg, Colo. (H. G. Smith). Scales slightly over 1 mm. long and 1.5 broad, with rounded margins and 7 to 9 apical radii; circuli very widely spaced.

Opsopæodus Hay. Proc. Biol. Soc. Wash., xxii, pl. iii, fig. 3. Scale broader than long, with few radii.

Orthodon Girard. Proc. Biol. Soc. Wash., xxii, p. 209-210, fig. 1. Scale oval, longer than broad.

Phenacobius Cope. Proc. Biol. Soc. Wash., xxii, p. 159; Biol. Bulletin, xx, pl. iv, fig. 24. Scale broader than long; radii few; apical circuli angulate in middle (*P. mirabilis*). In *P. mirabilis* the skin is thin, and the sculpture of the scales is clearly visible; in *P. scopifer* (from Longmont, Colo.) the skin is very thick, and the sculpture of the scales is not visible until it is removed.

Pimephales Rafinesque. Proc. Biol. Soc. Wash., xxii, p. 122; Biological Bulletin, xx, pl. v, fig. 26.

Platygnathus Gill, flathead chub. The scales of this genus have not been described, but I have examined a specimen of *P. physignathus* (Cope) from Salida, Colo., May, 1908 (Warren). There are 49 scales in the lateral line, covered by thick skin. Characteristic of the genus are the flatness of the head above and the falcate pectoral fins. Barbels distinct; gill filaments not fimbriate; peritoneum clear silvery. In the relatively large scales and small eyes it is like *Nocomis* rather than *Couesius*; the large vertically elongate nostrils are distinct from either, but rather nearer *Couesius*; the pigmentation and tuberculate middle of head above resemble *Couesius*. Scales about 3 mm. long and 4 broad, approximately semicircular, the basal outline gently convex, laterobasal corners distinct though obtuse; nucleus subbasal; circuli crowded basally, rather widely spaced laterally; inter-radial circuli irregular and very widely spaced, more or less inclined to be angulate in middle, radii apical only, 11 or 12. The skin is densely very minutely tuberculate.

Pogonichthys Girard, split-tail. Zoologischer Anzeiger, xxxvi, p. 479. An isolated genus in the American fauna. Scales quite large, about $5\frac{1}{2}$ mm. long and 5 broad; nucleus about $1\frac{1}{2}$ mm. from base; radii all apical, very numerous and close together, about 35; apical circuli not at all angled; laterobasal corners distinct; basal outline strongly convex. This is based on *P. macrolepidotus* (Ayres) from San Francisco (Dr. W. O. Ayres); the specimen in the British Museum, labeled *Leucosomus inæquilobus*.

Ptychocheilus Agassiz, squawfish, Proc. Biol. Soc. Wash., xxii, p. 159, pl. iii, fig. 2; Girard, Ichth. Mex. Boundary Survey, pl. xxxiv, fig. 2-4. Girard's figures show the more mature scales, in which the base is very distinctly produced.

Rhinichthys Agassiz, black-nosed dace. Proc. Biol. Soc. Wash., xxii, p. 157. In *R. cataractæ dulcis* from the Rio Grande in Colorado there are about 12 apical radii and five distinct basal ones. In *R. atronasus* from Spring Creek, Tenn., I found about 20 apical radii, but the outermost of these strictly lateral; the basal radii were only imperfectly indicated. In most respects the scales of *dulcis* and *atronasus* are essentially alike. This is closely related to *Agosia* (*A. oscula*, *A. nubila*), in which there are radii all around, the basal well developed.

Richardsonius Girard. Proc. Biol. Soc. Wash., xxii, p. 159-160 (as *Leuciscus*); t. c., p. 216-217; t. c., p. 186, fig. 1 (*R. thermophilus*); Biological Bulletin, xx, pl. ii, fig. 14 (*orculti*), pl. iii, fig. 15 (*pulchellus*), fig. 16 (*carletoni*), fig. 17 (*thermophilus*); Girard, Ichth. Mex. Boundary Survey, pl. xxxiv, fig. 6-8 (*pulchellus*), pl. xxxiii, fig. 2-4 (*gibbosus*), pl. xxxii, fig. 2-4 and 6-8 (*nigrescens* and *pulchra* = *pulchellus*). *R. orculti* (Eigenmann & Eigenmann) is the type of the subgenus *Temeculina* Cockerell; *R. pulchellus* (Baird & Girard) represents the subgenus *Tigoma* Girard; *R. thermophilus* Evermann & Cockerell represents *Richardsonius* s. str.; *R. carletoni* (Kendall) is provisionally referred to subgenus *Cheonda* Girard.

Richardsonius gibbosus is figured by Girard as having radii all around the scale, apical, lateral, and basal, and a scale from the abdominal region has a polygonal pattern in the nuclear field. According to the scales, therefore, this fish agrees with *Temeculina*. Placed in *Richardsonius*, the name *gibbosus* (*Gila gibbosa* Baird & Girard 1854) has priority over *nigra* Cope 1876, and *intermedia* Girard 1856, the latter said by Gilbert & Scofield (1898) to be identical. The name *gibbosus* is not a homonym if the fish is not placed in *Leuciscus*. According to Girard's figures, *R. pulchellus* has occasional poorly defined basal radii, but the whole appearance is very different from that of *R. gibbosus*. The scale of *R. intermedius* (there regarded as distinct from *gibbosa* or *nigra*) was briefly described in Proceedings of the Biological Society of Washington, volume xxii, page 159, and was found to fall in the same immediate group as *R. pulchellus* (*nigrescens*); this does not agree with Girard's figures of *gibbosus*, but certainly his scales came from a much older fish. It remains to be seen whether *R. intermedius* is really distinct from *gibbosus*, but in view of the facts stated it will probably be best to follow Jordan & Evermann in so treating it. There is, however, a further complication arising from the publication of *Gila gracilis* Baird & Girard 1853, which Gilbert & Scofield (1898) say is not *G. robusta*, but is "*Leuciscus intermedius*." The name *gracilis* is not a homonym if the fish is not referred to *Leuciscus*, and it has priority even over *gibbosus*, so that in any event *Richardsonius gracilis* (Baird & Girard) must be a valid specific name. Another change of nomenclature is required in the case of *Richardsonius alicia*. The name *Tigoma gracilis* Girard 1856, is not available; but *Squalius copei* Jordan & Gilbert 1880 is and the species becomes *Richardsonius copei* (Jordan & Gilbert).

Rutilus auctt. Amer. = *Myloleucus*.

Semotilus Rafinesque, chub. Proc. Biol. Soc. Wash., xxii, p. 162, pl. iii, fig. 4 (*S. corporalis* and *S. atromaculatus*). A western form of *S. atromaculatus*, obtained by Mr. H. G. Smith at Julesburg and Sterling, Colo., appears to be subspecifically distinct and may be known as *S. atromaculatus macrocephalus* (Girard). In its scales it approaches *S. corporalis*.

Siphateles Cope. Proc. Biol. Soc. Wash., xxii, p. 161 (as *Rutilus olivaceus*); t. c. p. 217.

Tiaroga Girard. Girard, Ichth. Mex. Boundary Survey, pl. xxviii, f. 12-14. The scales have radii all around, and are transversely oval in form, altogether in the manner of *Chrosomus*.

Although there is still much to be learned about the scales of American Cyprinidæ, the facts discussed above indicate very well that our fauna is essentially distinct from that of the Old World, with, however, the nearest allies of Old World types mostly in the far West; also, I believe that any fundamental separation of our genera into an herbivorous group with long intestine and a mainly carnivorous one with short intestine is artificial. The herbivorous group is to be divided into several which seem to be properly associated with corresponding groups in the carnivorous series.

(B) OLD WORLD GENERA.

My material representing Old World Cyprinidæ is almost wholly from the British Museum, which is herein abbreviated to B. M.

Abramis Cuvier, breams. Proc. Biol. Soc. Wash., xxii, p. 211-213; Zool. Anzeiger, xxxvi, p. 478, fig. 3 (*A. elongatus*).

Acanthorhodeus Bleeker. *A. tanianalis* is a very deep-bodied fish from Shanghai (Swinhoe, B. M.); the scales, as usual in the Rhodeines, are extremely broad; length a little over 5 mm., breadth fully 8. The basal circuli are dense, those at the sides more widely spaced; the very numerous radii, all apical, are wavy, or more or less zigzag. The region of the radii is finely striate with lines of growth, and in the interradii spaces are spots due to a kind of pitting. (Pl. xxxii, fig. 2.) Zool. Anzeiger, xxxvi, 477.

Alburnus Heckel, bleak. Zool. Anzeiger, xxxvi, p. 477. (*A. lucidus* and *filippii*.)

Amblyrhynchichthys Bleeker. *A. truncatus* from the Menam River, Siam (Royal Siamese Museum; B. M.), has subquadrate scales with very thin apical margins; length about $3\frac{1}{2}$, with slightly over

4 mm.; nucleus well basad of middle; laterobasal corners very distinct; basal margin thrown into two or three prominent folds; basal radii few, delicate and irregular; apical radii about ten, very slender, the outer ones broad outward; apical area with growth striæ, but free from circuli (here agreeing with *Gobio*, *Saurogobio*, etc.); circuli very numerous, the lateral ones more widely spaced. The outline of the scale, especially the basal part, is practically as in *Barbus mahecola* (Biol. Bull., xx, pl. III, fig. 19), but the sculpture more resembles that of *Gobio* and its allies.

Aspidoparia (Heckel) Bleeker. Zool. Anzeiger, xxxviii, p. 87, fig. 5.

Ballerus Heckel. Proc. Biol. Soc. Wash., xxii, p. 212-213.

Barbichthys Bleeker. Zool. Anzeiger, xxxvi, p. 252, fig. 2 and 3. The scale of *B. lævis* from Siam is large, about 10 mm. long and 8 broad, with prominent though rounded laterobasal corners; basal margin thrown into two broad wave-like lobes; a single, median, basal radius; numerous apical radii, but only about four, which are strong, reaching the nuclear area, whereas in the marginal region there are over 30; apical field with the circuli broken up, forming pustules; lateral and basal circuli dense and regular. The figures in the Zoologischer Anzeiger show the relation of the circuli to the pustules.

Barbus Cuvier & Valenciennes, barbel. Proc. Biol. Soc. Wash., xxii, p. 157-158; xxiii, p. 145-148, pl. III, fig. 1 (*B. chrysopoma*), fig. 3 (*batesii*), fig. 4 (*barbus*), fig. 5 (*ksibi*), fig. 6 (*pleurotaenia*), fig. 9 (*grahami*); Zool. Anzeiger, xxxvi, p. 479; Biol. Bulletin, xx, pl. III, fig. 19 (*mahecola*); Boulenger, Catalogue Freshwater Fishes of Africa, vol. II, p. 2, fig. 1 (*bynni*, *pleurogramma*, *perince*). The *Barbus compressus* mentioned in Proc. Biol. Soc. Wash., xxiii, p. 146, is from Fort Stedman, Shan States, 3,000 feet (E. W. Oates; B. M.). This is *B. compressus* Boulenger, Ann. Mag. Nat. Hist., ser. 6, xii, 1893, p. 202; not *B. compressus* Day, Proc. Zool. Soc. Lond., 1869, p. 555. With Dr. Boulenger's permission, I alter *B. compressus* Boulenger to *B. compressiformis* n. n.

Barilius Hamilton Buchanan. Proc. Biol. Soc. Wash., xxiii, p. 143-144, pl. III, fig. 10 (*B. loati*).

Barynotus Günther. I believe this generic name is preoccupied in Coleoptera. *B. luteus* from Schiraz (Marquis Doria; B. M.) has very large reddish quadrate scales, about 13 mm. long and broad; nucleus about 5 mm. from base; circuli very fine, about 10 or 12 basal radii and about 35 apical ones, the latter wavy and many of them imperfect. In size, color, and form this is like the scale of *Semiplotus maclellandi*, except that the latter is considerably broader than long. In detail there are rather important differences, though of degree rather than of kind. In the *Semiplotus* the basal radii are very few and weak, while there are numerous delicate but distinct lateral radii, represented only by a few irregular lines in *Barynotus*. In both the apical radii are wavy and the interradial spaces are tuberculate, but the tubercles are more prominent in *Semiplotus* and extend almost to the nucleus, whereas in *Barynotus* they do not go beyond the skin-covered area.

Capoeta Valenciennes. (Pl. xxxiv, fig. 13.) Proc. Biol. Soc. Wash., xxiii, p. 149. According to Berg, *C. steindachneri* Kessl is a synonym of *C. heratensis* Keyserling.

Carassius Nilsson, goldfish. Zool. Anzeiger, xxxvi, p. 480.

Catla Cuvier & Valenciennes. *Catla catla* (*Cyprinus catla* Hamilton Buchanan; *Catla buchanani* Cuvier & Valenciennes) from Calcutta (F. Day; B. M.) has large elongate scales with rectangular basal corners; length 11, breadth 8 mm. The nucleus is about $4\frac{1}{2}$ mm. from the base; the base has five or six irregular but prominent radial folds; apical radii about 16, delicate, straight, many incomplete; lateral radii variable, when distinct similar to those of *Semiplotus*; basal circuli irregular and not so dense as usual; apical circuli distinct, longitudinal, the inner ones directed more or less mesad, approaching the condition so well developed in *Cirrhitina jullieni*, but not nearly so extreme. According to Day, *Catla catla* reaches a length of at least 6 feet; my material is from a much smaller fish.

Chanodichthys Bleeker. *C. pkinensis* from Shanghai (Swinhoe; B. M.) has rather large broad-oval scales, about 10 mm. long and slightly over 8 broad; nucleus nearly central; circuli finely evanescent in the apical region, which is somewhat rugose; no basal or lateral radii, but about 21 apical, some incomplete. The scale examined is not symmetrical and probably not quite normal.

Chela Hamilton Buchanan. (Pl. xxxii, fig. 4.) Proc. Biol. Soc. Wash., xxiii, p. 142, pl. III, fig. 12 (*C. argentea*).

Chelathiodops Boulenger. Proc. Biol. Soc. Wash., xxiii, p. 141-142, pl. III, fig. 11 (*C. bibie*).

Chondrostoma Agassiz. (Pl. xxxii, fig. 5.) Proc. Biol. Soc. Wash., xxii, p. 210; Zool. Anzeiger, xxxvi, p. 477.

Cirrhhina Cuvier. Proc. Biol. Soc. Wash., xxiii, pl. iii, fig. 8 (*C. jullieni*). The scales of four species of *Cirrhhina*, obtained from the British Museum, are so distinct as to suggest that they can not all be truly congeneric.

Scale much longer than broad (length 9, breadth 7 mm.) with broadly rounded apex and squared base; circuli fine, wanting in the apical field, where they are replaced by coarse tubercles; basal radii about a dozen, delicate, many incomplete; apical radii few and irregular; nucleus a short distance basad of middle (Cutch, F. Day). *C. mrigala* Hamilton Buchanan

Scale slightly longer than broad, or about as broad as long.

Scale 9 mm. long, $8\frac{1}{2}$ broad; laterobasal corners distinct; nucleus considerably basad of middle; no basal radii; apical radii over 20, mostly well formed; circuli replaced by transversely elongate tubercles in the apical region covered by skin, but in the central region below this by vermiform markings *C. chinensis* Günther (Haslar collection).

Scale $5\frac{1}{4}$ mm. long, $4\frac{3}{4}$ broad; laterobasal corners distinct; nucleus very far basad; a few weak submedian basal radii; apical radii about eight, distinct, wide apart; apical circuli very distinct, wide apart, sloping toward the middle (Stung-Strang, Paris Museum).

C. jullieni (from type lot)

Scale conspicuously broader than long (length $2\frac{3}{4}$, width $3\frac{1}{2}$ mm.); nucleus far basad; basal radii about 20, very short, submarginal; apical radii over 20, not or hardly converging; circuli absent in apical region, but a small amount of tuberculation; broad nuclear area with fine very irregular reticulation; probably latinucleate scales (Kushk, Afghan Boundary Commission).

C. afghana Günther

The scales of *Cirrhhina* are in general (excepting *C. afghana*) much like those of *Osteochilus* or *Labeo*.

Thus, as regards the sculpture of the apical field, *C. jullieni* may be compared with *Labeo chrysophekadion*, while *C. mrigala* and *C. chinensis* may be compared with *Labeo sindensis*, etc.

May we not suppose that the groups of *Osteochilus* and *Cirrhhina* have arisen from different groups of *Labeo*?

Cosmochilus. I have a lateral line scale of *C. falcifer*, a very large fish from Sarawak, Borneo (C. Hose; B. M.). The scale is of the quadrate type, strongly orange tinted, about 20 mm. long and broad; lateral line canal bifid at the apical end; nuclear field extremely large, granular; basal radii very numerous, but wholly marginal and submarginal; apical radii very numerous, irregular, wavy; no circuli in apical field. *C. harmandi* from the Menam River, Siam (Royal Siamese Museum; B. M.) is represented by much smaller, pallid scales, about 7 mm. long and 6 broad, but of the same subquadrate form. Both basal and apical radii are fewer and more irregular, the basal longer, the apical wavy. Except for the size and minor details, the scales of the two species are wholly of the same type.

Crossocheilos Bleeker. (*Crossochilus* auctt.) I follow the British Museum labels, but Day refers *C. latia* and *C. reba* to *Cirrhhina*. The scales before me are separable as follows:

Scales large and elongate (length about $11\frac{1}{2}$ mm., breadth about $6\frac{1}{2}$), parallel-sided; circuli dense, those of the apical field transformed into tubercles in part, but toward the nucleus into vermiform lines, and in the extreme apical region wholly wanting; nucleus only about 3 mm. from base; three or four distinct basal folds; apical radii numerous, more or less wavy, converging toward the middle; lateral radii delicate, variable, usually distinct (Madras, F. Day; B. M.).

C. reba (Hamilton Buchanan)

Scales smaller and much less elongate. 1

1. Scales evidently longer than broad. 2

Scales not or little longer than broad. 3

2. Basal margin gently convex, not wavy; laterobasal corners more rounded; basal radii very few and feeble; apical radii numerous, parallel; scale (not adult) about $5\frac{1}{2}$ mm. long and 4 broad (Simla, F. Day; B. M.). *C. latia* (Hamilton Buchanan)

Basal margin wavy or broadly crenate; laterobasal corners sharper; basal radii very irregular, but distinct; apical radii numerous, many imperfect; nucleus about $1\frac{1}{2}$ mm. from base; scale about 7 mm. long and 6 broad. (Java; B. M.). *C. oblongus*

3. Nucleus less basad ($1\frac{3}{4}$ mm. from base in scale 5 mm. long and $4\frac{1}{2}$ broad); middle interradii (apical) region strongly tuberculate (Ningpo, F. W. Styan; B. M.). *S. styani* Boulenger

Nucleus more basad; middle interradii region not tuberculate (Cashmere, T. C. Jordon; B. M.)

C. barbatulus

C. reba seems to stand apart from the others. Day says of *C. latia*, "this fish has much the character of a loach or of a *Discognathus*, adhering to stones in the beds of rivers." Superficially the scales of *C. reba* look like those of *Rohita lineata*, but they are very different in detail, having a different apical field and the nucleus very much more basad than in *Rohita*.

Culter. This genus has rather small (about 4 mm. diameter) circular scales, with a central nucleus, rather few and weak apical radii, and no basal. The basal circuli are very dense. I have two species from the British Museum; *C. ilishaeformis* from Kiu Kiang (Styan) and *C. erythropterus* Basilevsky from the River Keroulen, Mongolia (Chaffanjon). They are very much alike, but in *erythropterus* the apical radii are more distinct, and the apical margin is crenate. (Pl. xxxiv, fig. 14.)

Cyprinus Linnæus, carp. Zool. Anzeiger, xxxvi, p. 480, fig. 2 (p. 478). The figure represents the hybrid *C. kollarii*.

Dangila Cuvier & Valenciennes. From the British Museum I have the scales of three species:

Scales large, much longer than broad (length 16 mm., breadth 10); strongly orange-tinted; parallel-sided; nucleus far basad; weak radii all around; middle apical region strongly tuberculate (in a deep place in the cavity, Salem, Capt. Mitchell).....*D. leschenaultii*
Scales much smaller, not longer than broad; not orange-tinted.....²
1. Apical field distinctly tuberculate; scale about 5 mm. long and broad. (Deli, Sumatra, Moesch.)
D. kuhlii (cf. Zool. Anzeiger, xxxvi, p. 478, where for *gobiiiform* read *gobioniform*.)
Apical field merely striate; scale about 7 mm. long and broad (mouth of Patani River, Annandale & Robinson).....*D. cuvieri*

Danio Hamilton Buchanan. Type of subfamily Danioninæ. Zool. Anzeiger, xxxviii, p. 85, fig. 1, 2; (*D. devario* and *D. aequipinnatus*.)

Diptychus Steindachner. *D. maculatus* Steindachner from Nepaul (F. Day; B. M.) was examined, but no scales were found; the skin is very thickly beset with small spots of ferruginous pigment. According to Day, there are small scattered scales, which I evidently overlooked.

Discognathus Heckel. Proc. Biol. Soc. Wash., xxiii, p. 149-150. The species described belong to the subgenus *Garra* Hamilton Buchanan.

Engraulicypris Günther. *Neobola* Vinciguerra is now regarded by Boulenger as a synonym. Proc. Biol. Soc. Wash., xxiii, p. 143 (*Neobola*) and 144.

Gnathopogon Bleeker. I have examined *G. gracilis* (*Capoeta gracilis*) from Superghan, Nalzow Chai River (R. T. Günther; B. M.), and have given some account of it in Proc. Biol. Soc. Wash., xxiii, p. 149. The scales are about $4\frac{1}{3}$ mm. long and $3\frac{3}{4}$ broad; nucleus well basad of middle; laterobasal corners prominent; basal radii irregular, few and very feeble; apical radii distinct, about 15, with strong tubercles between.

Gobio Cuvier, gudgeon. Zool. Anzeiger, xxxvi, p. 477-478; Biol. Bulletin, xx, pl. v, fig. 27.

Gymnocypris Günther. I examined *G. waddellii* Regan (Yamdok Lake, Tibet, 14,800 ft., L. A. Waddell; B. M.) but found no scales. The skin is sepia brown with darker, reddish dots.

Hemibarbus Bleeker, Proc. Biol. Soc. Wash., xxiii, p. 146-147 (under *Barbus*). According to L. S. Berg, *H. barbus* or *schlegeli* is to be called *H. labeo* (*Cyprinus labeo* Pallas), with *maculatus* (Bleeker) as a variety.

Hypophthalmichthys Bleeker. In Günther's Catalogue this is considered typical of a distinct section or subfamily, Hypophthalmichthyina, or as we should now say, Hypophthalmichthyinæ. I examined *H. nobilis* from Shanghai (Swinhoe; B. M.), but by an unfortunate accident the scale was lost when in the hands of the photographer.

Ischikauia Jordan & Snyder. Zool. Anzeiger, xxxviii, p. 86, fig. 3.

Labeo Cuvier. Proc. Biol. Soc. Wash., xxiii, p. 150-151, pl. iii, fig. 2 (*L. fimbriatus*), fig. 7 (*L. senegalensis*); Biol. Bulletin, vol. xx, pl. I, fig. 8 (*L. sladoni*).

Leptobarbus Bleeker. *L. hoevenii* (Tinjjar River, 200 miles from the sea, C. Hose; B. M.) is a fish with terminal mouth, having very large quadrate scales, my specimen 18 mm. long and 14 broad. The basal radii, about 14, are very delicate and irregular; lateral radii more or less developed; apical radii about 33; circuli evanescent apically. (Pl. xxxiv, fig. 15.)

Leptocypris Boulenger. Proc. Biol. Soc. Wash., xxiii, p. 144.

Leuciscus Cuvier, dace, chub, etc. Proc. Biol. Soc. Wash., xxii, p. 215-216 (including not only *Leuciscus* proper, but also *Rutilus* Rafinesque, *Pigus* Bonaparte, *Cephalus* Bonaparte, *Idus* Heckel, and *Scardinus* Bonaparte); Zool. Anzeiger, xxxvi, p. 479-480; Biol. Bulletin, xx, p. 371, pl. 1, fig. 7 (*L. illyricus*), pl. 11, fig. 10 (*L. rutilus*), fig. 11 (*L. friesii*), fig. 12 (*L. hakuensis*), fig. 13 (*L. jouyi*).

Leucogobio Günther. I have *L. mayedæ* (Jordan & Snyder) from Lake Biwa, Japan (Jordan & Snyder). The scales are much broader than long (length about $3\frac{1}{2}$ mm., breadth $5\frac{1}{3}$), but otherwise entirely of the type seen in *Gobio*, with the same radii, circuli, etc.

Luciosoma Bleeker. I have three species from the British Museum. The scales are large and subquadrate; basal, lateral, and apical radii distinct, the lateral oblique, not or hardly at all directed toward the nucleus, except when the lower end is abruptly bent and turned inward; circuli very fine, but absent in the granular or striate apical field; laterobasal corners distinct. The species are separated thus:

- Nucleus central or nearly; scale 13 mm. long and 10 broad; about 10 apical radii; fish with dorsal fin very far back (W. Siam, Carl Bock).....*L. harmandi*
 Nucleus conspicuously basad of middle..... 1
 1. Scale reddish, 11 mm. long, $10\frac{1}{4}$ broad; about 14 apical radii; fish with dorsal far back (Kapit, Rejang district, Sarawak, C. Hose).....*L. pellegrini* Popta
 Scale white, 8 mm. long and 7 broad; about 14 apical radii; fish with row of large spots down side (Upper Baram River, C. Hose).....*L. trinema*

In scale characters the genus is very compact and except for the difference in the position of the nucleus the characters cited may not be specific. Scales of *L. trinema* are figured on plate xxxiii, figure 7.

There is a rather strong resemblance between the scales of *Luciosoma* and *Leptobarbus hoevenii*, but in *Luciosoma* the apical radii are spreading, fanlike, in the *Leptobarbus* they are parallel.

Macrochirichthys; see *Chela macrochir*; Proc. Biol. Soc. Wash., xxiii, p. 142. Fowler (1905) treats *Macrochirichthys* as a distinct genus.

Myloleucus Günther. Cope published a genus of the same name at about the same time, but I believe the American genus has priority.^a *M. æthiops*, from Kiu-Kiang (Styan; B. M.), has large scales, approximately circular, but with more or less evident laterobasal angles; length 12, breadth 11 mm.; nucleus central; area covered by skin unusually large, extending to nucleus, skin densely speckled with red-brown pigment; basal circuli quite dense; slight basal folds, but no radii; apical radii about a dozen, feeble; apical circuli strong, longitudinal, converging toward the middle, where they meet at very acute angles. A scale approaching the type of *Cirrhitina jullieni*.

Neobola Vinciguerra; see *Engraulicypris*.

Opsariichthys Bleeker. Zool. Anzeiger, xxxvi, p. 252, fig. 1 (*O. morrisonii*); xxxviii, p. 87. The species figured is now to be referred to *Zacco*.

Oreinus McClelland. (Pl. xxxiv, fig. 16.) A genus of mountain fishes with small scales, circular or broad-oval or (*grahami*) sometimes subtriangular, with nucleus central or nearly, circuli not very dense and rather widely spaced radii all around. They are therefore of the general type of *Chrosomus* and *Phoxinus*. The genus on scale characters is quite compact. Three species have been examined in the British Museum:

O. grahami. Tongchuenfu, Yunnan (J. Graham). Scales 2 to $2\frac{1}{4}$ mm. diameter.

O. plagiostomus (Heckel) Assam (F. Day). Scales about 1 by $\frac{3}{4}$ mm.

O. richardsonii (Gray & Hardwicke) Nepal (B. H. Hodgson). Scales a little smaller than those of *O. grahami*. This genus is referred to the Schizothoracinae.

Osteobrama Heckel. Day calls this genus *Rohtee*. Dr. G. A. Boulenger writes (litt., May, 1910): "*Rohtee* Sykes and *Osteobrama* Heck. are synonyms. Both genera were established in the same year. I don't know which has really priority." I have four species from the British Museum.

^a Dr. D. S. Jordan kindly informs me that Cope's name has about a year's priority. *Myloleucus* Günther may be changed to *Myloleucops* n. n., our fish becoming *Myloleucops æthiops*.

- Scales elongate (8 mm. long, slightly over $3\frac{1}{2}$ broad), parallel sided, nucleus 2 mm. from anterior end; posterior end broadly and shallowly emarginate; circuli fine and dense; a single delicate radial line runs down the middle of the scale from the nucleus to the posterior margin, but otherwise there are no basal radii; apical field rugose, with very weak radii (Sittang River, E. W. Oates)..... *O. microlepis*
- Scales circular or nearly; nucleus nearly central; no basal radii, but the basal region more or less undulate..... 1
1. Scales broader than long; only feeble rudiments of basal radii; about 13 wavy apical radii (Sittang River, E. W. Oates)..... *O. alfrediana*
- Scales larger (diameter $4\frac{1}{2}$ mm.); apical radii few, strong but very irregular and broken, wavy; a very deep-bodied fish (Sittang River, E. W. Oates)..... *O. feae* Vinciguerra
- Scales smaller (diameter about 3 mm.), apical field without circuli, but with weak and broken wavy radii (Sittang River, E. W. Oates)..... *O. cotio* (Hamilton Buchanan)

The last three seem closely allied, but *O. microlepis* is very different and is probably not truly congeneric. In Günther's Catalogue *Osteobrama* stands next to *Chanodichthys*. The scale of *Chanodichthys*, without basal radii, is in fact of a similar type, but much larger, with the numerous apical radii not distinctly wavy.

Osteochilus Günther. Zool. Anzeiger, xxxvi, p. 253, fig. 4 (*O. kahajanensis*). I have seven species from the British Museum, which are separable thus:

- Apical interradiar area striate with longitudinal converging circuli..... 1
- Apical interradiar area evidently tuberculate, the circuli broken up..... 2
1. Scales about 7 mm. long and $5\frac{1}{2}$ broad (Menam River, Siam; Royal Siamese Museum). *O. schlegelii*
- Scales about 4 mm. long and $3\frac{3}{4}$ broad (Menam River, Siam; Royal Siamese Museum). *O. melanopleurus*
2. Scales very large, 14 mm. long and 13 broad; apical radii wavy, basal radii very few and irregular (Baram River, Sarawak; C. Hose)..... *O. hasseltii* (Cuvier & Valenciennes)
- Scales smaller; apical radii essentially straight..... 3
3. Lateral radii few, reaching-nuclear area; scales about 7 mm. long and 6 broad (Sittang River; E. W. Oates)..... *O. neilli* (Day)
- Lateral radii numerous, all or most failing to reach nuclear area..... 4
4. Basal margin strongly trilobed (Deli, Sumatra; Moesch)..... *O. waandersii*
- Basal margin weakly undulate..... 5
5. Scale about 10 mm. long and 9 broad; skin pale with dark dots. (Baram district; C. Hose). *O. kahajanensis*
- Scale about 7 mm. long and 6 broad; skin brown (Tinja River, 200 miles from sea; C. Hose). *O. vittatus*

All are broadly rounded apically, essentially truncate basally, with evident laterobasal corners; nucleus far toward the base (least so in *O. neilli*); apical radii well developed, basal very poorly, feeble and irregular. The genus is a compact one on the scales, and the specific distinctions given are probably not all valid. (See also remarks under *Cirrhinna*.)

Paracheilognathus Bleeker. Proc. Biol. Soc. Wash., xxii, p. 157; Zool. Anzeiger, xxxvi, p. 477. Scales of *P. rhombus* are about $2\frac{3}{4}$ mm. long, $4\frac{3}{4}$ broad; circuli not at all dense.

Parapelecus Günther. *P. argenteus* from Kiu-Kiang (Styan; B. M.) is a remarkable fish, with the scales inserted obliquely, and the lateral line abruptly bent. The scales are about 4 mm. long and $6\frac{3}{4}$ broad, covered with thin skin to the base. There are fine basal circuli, but no basal radii; in the apical field the circuli are wanting, but there are numerous irregular delicate radii. Thus the scale combines the shape of the Rhodeines with the sculpture of the *Gobio* group. Except for the larger size and covering of pinkish skin, the scales are extremely like the broader ones of *Leucogobio mayeda*.

Phoxinellus Heckel. Proc. Biol. Soc. Wash., xxii, p. 216. The locality given as Oued el Mahd should be Oued (or Wed) el Mahdi; the printer took the i for a semicolon. The two lots of scales represented *Phoxinellus chaignoni* (Vaillant) and *P. callensis* (Guichenot), which Boulenger now regards as distinct, though very closely allied. I fail to find any difference in the scales of the two.

Phoxinus Rafinesque. Proc. Biol. Soc. Wash., xxii, p. 186 and p. 216; Zool. Anzeiger, xxxvi, p. 476.

Pseudogobio Bleeker. Zool. Anzeiger, xxxvi, p. 478, fig. 1 (*P. esocinus* Schlegel).

Rasbora Bleeker. Proc. Biol. Soc. Wash., xxiii, p. 144.

Rhinogobio Bleeker. Biol. Bulletin, xx, p. 371, pl. II, fig. 9. Scale elongate, with broad truncate base.

Rohita Valenciennes. *R. lineata* from the Sittang River (E. W. Oates; B. M.), has elongated scales, about 10 mm. long and $6\frac{1}{2}$ broad, the truncate base with a broad median lobe, bounded by the basal radii, which are two or three in number. Nucleus a short distance basad of center; gently curved delicate lateral radii; apical radii evanescent or extremely feeble; skin-covered area strongly tuberculate. The shape of the scale is very like that of *Labeo fimbriatus*. (Pl. XXXIII, fig. 9.)

Saurogobio Bleeker. Zool. Anzeiger, xxxvi, p. 478. Scales elongated; those of *S. dumerilii* much like those of *Rhinogobio typus*; both species collected by Styán at Kiu-Kiang.

Scaphiodon Heckel. Scales broader than long, with small subbasal nucleus; apical radii numerous, but no basal ones; interradial area tuberculate. I have two species from the British Museum, very much alike, but separable as follows:

Base with a very prominent rounded lobe; laterobasal corners very distinct; skin pallid, speckled with light brown (Sind; F. Day). *S. watsoni* Day

Basal margin convex, but not lobed; laterobasal corners indistinct; skin brown, speckled with darker (Muscat, Arabia; A. S. G. Jayakar). *S. muscatensis*

Except for the broader scales and denser sculpture there is an evident resemblance to *Capoeta*.

This resemblance doubtless extends to other than scale characters, for Cuvier and Valenciennes included species of *Scaphiodon* in *Capoeta*. *S. muscatensis* is figured on plate xxxiii, figure 10.

Scaphiodontichthys Vinciguerra. My two scales of *S. burmanicus*, from Mount Mooleyit (Fea; B. M.), are both latinucleate; the scale is broader than long (about 7 by 8 mm.), considerably larger than that of *Scaphiodon*, with numerous apical radii but no basal; the basal margin is convex, without any lobe, and without laterobasal corners. The scale is structurally close to that of *Scaphiodon*.

Schizopygopsis Steindachner. I microscopically examined the skin of *S. stoliczkae* (Seistan, Helmund River, Col. McMahon; B. M.) and *S. younghusbandi* (Lhasa, Tibet, H. J. Walton; B. M.), but found no scales. The skin in *S. younghusbandi* is clear, profusely dotted with lichenoid spots of dark brown pigment.

Schizothorax Heckel. Biol. Bulletin, xx, pl. iv, fig. 22 (*S. biddulphii*); Zool. Anzeiger, xxxvi, p. 476.

In *S. intermedius* (Kashgar; B. M.) the scales are elongate as in *S. biddulphii*, and the sculpture is in all respects the same, except that it is less dense. (Pl. xxxiii, fig. 11.)

Semiplotus Bleeker. In *Semiplotus semiplotus* (Cyprinus semiplotus McClelland, *Semiplotus maccllellandi* Bleeker) from Assam (F. Day; B. M.) the scales are quite large, reddish, broader than long (length 13, breadth 15 mm.); nucleus a short distance below the middle; basal radii 3 or 4, feeble; slender curved lateral radii; apical radii very numerous, wavy; apical field coarsely tuberculate. The scale is of entirely the same general type as that of *Barynotus luteus*, but shorter, with much less prominent laterobasal corners, and fewer and feebler basal radii. The color is the same in both, and the differential characters cited are doubtless more or less variable. (Pl. xxxiii, fig. 12.)

Squaliobarbus Günther. Biol. Bulletin, xx, p. 371, pl. I, fig. 6 (*S. curriculum*).

Tinca Cuvier. Zool. Anzeiger, xxxvi, p. 476; Biol. Bulletin, xx, p. 373, pl. iv, fig. 21.

Tylognathus Heckel. Day treats this as a synonym of *Labeo*. I have five species from the British Museum. They agree in having numerous apical radii and the apical field tuberculate. So far as the material goes, they appear to be separable as follows:

The subquadrate scale broader than long (about 7 mm. long and 8 broad); laterobasal corners very prominent; basal radii very numerous, but fine and irregular; apical radii strong, more or less wavy, the interradial tubercles very strong *T. ("Lobocheilus") lehat*

The subquadrate scale a little longer than broad (about 8 mm. long and $7\frac{1}{2}$ broad); general characters like the last, but apical radii scarcely wavy, and interradial tubercles weaker (Pata R.; C. Hose) *T. hispidus*

Scale conspicuously longer than broad, parallel-sided, shape like that of *Labeo fimbriatus*. 1

1. Scale about 12 mm. long and 8 broad (Bowany R.; F. Day). *T. ariza* (Buchanan)

Scale about 7 mm. long and 4 broad, but fish not adult (Madras; F. Day). *T. boga* (Buchanan)

Scale about $5\frac{1}{3}$ mm. long and $3\frac{1}{2}$ broad (Poona; Lieut. Col. Playfair). *T. striolatus*

The following Asiatic *Labeo* have scales of the *Tylognathus* type, or approximating it; *L. sindensis*, *L. falcatus*, *L. bicolor*, *L. sladoni*, *L. ricnorhynchus*, *L. kontius* (nearly shape and size of *T. ariza*, but less

elongate), *L. leschenaultii* (looks like *T. ariza*, but differs by strong basal radii, which are entirely absent in *T. ariza*), *L. bata* (quite like *T. ariza*, with no basal radii), *L. pangusia*, *L. nigripinnis*, *L. kawrus*, *L. microphthalmus*. Several others approach the same type quite closely, and it is evident that so far as the scales go, *Tylognathus* can not be separated from *Labeo*.

Varicorhinus Ruppell. Proc. Biol. Soc. Wash., xxiii, p. 148.

Xenocypris Günther. Zool. Anzeiger, xxxvi, p. 253, fig. 5 (*X. argentea*). I have two species from the British Museum, both having pale subcircular scales.

Scale about $5\frac{1}{2}$ mm. long and $5\frac{3}{4}$ broad; laterobasal corners rounded; no basal radii; circuli in inter-radial (apical) region strong, transverse; nucleus almost central (Kiu-Kiang; Styan).

Scale about $3\frac{2}{3}$ mm. long and $3\frac{1}{2}$ broad; laterobasal corners more evident; no basal radii; apical radii 7 or 8, the interradii circuli transverse, strong, widely spaced; nucleus far basad of middle (mountain streams near Kiu-Kiang; Styan).....*X. microlepis*
.....*X. argentea* Günther

In the apical field there is a strong resemblance to *Chondrostoma*, but that genus has well-developed basal radii. See also Zool. Anzeiger, xxxviii, p. 86.

Zacco Jordan & Evermann. Zool. Anzeiger, xxxviii, p. 86, fig. 4.

CATOSTOMIDÆ. Suckers and buffalo-fishes.

The scales of the Catostomidæ are usually quite large, and resemble those of the Old World Cyprinidæ in most respects. For figures see Proceedings Biological Society of Washington, volume xxii, page 158, figure 2 (*Catostomus griseus*; the figure is printed upside down); Biological Bulletin, volume xx, plate 1, figure 3 (*Moxostoma aureolum*), and figure 4 (*Pantosteus santa-anæ*). In every case the basal radii are well developed. The scales of *Moxostoma cervinum* Cope, showing two types, one reticulated, are described in Science, July 28, 1911, page 126.

Subfamily ICTIOBINÆ. Buffalo-fishes.

In the carp sucker, *Carpiodes velifer* (Rafinesque), the scales from just below the front of the dorsal fin are broader than long, but those from between posterior end of dorsal and lateral line are longer than broad. The scales studied are from a fish about $4\frac{7}{8}$ inches long, from the Wabash River, Indiana (Bureau of Fisheries). Apical margin broadly rounded; laterobasal angles distinct; base rounded, forming a single broad lobe, between which and the laterobasal angles the margin is concave; circuli very distinct, in the apical field only about half as closely set as laterally and basally; apical radii few, usually three, one median, and a curved one on each side, but sometimes five are present; basal radii numerous, about 30, or more counting imperfect ones, close together; nucleus central or almost. Latuncleate scales are coarsely and irregularly reticulate in the middle. Compared with the Catostomine series, this falls with *Catostomus commersonii*, from which it is at once separated by the character of the apical radii.

Subfamily CATOSTOMINÆ. Suckers.

Scales very small; oval, oblong, or subcircular, without laterobasal corners..... 1
Scales larger, often very large, with evident laterobasal corners..... 4
1. Radii all around; nucleus more or less apicad of middle (Boulder County, Colo.).....

.....*Catostomus griseus* (Girard)
Radii apical and basal, the lateral basal ones usually not pointing to the nucleus, but when complete strongly crooked above, the bent basal end then pointing to the nucleus; nucleus central or basad of center..... 2

2. Nucleus nearly central, or moderately basad of middle..... 3
Nucleus far basad of middle of the very small scales (Russian River, Cal.; Stanford University).

.....*Catostomus occidentalis* Ayres
3. Scales often broader than long, but variable (Oregon).....
Scales longer than broad, but little different from the last (California).....*C. humboldtianus* Snyder
Scales closely resembling the last, but with lateral circuli more developed, so as to approach
C. griseus, except for the more basad nucleus (California).....*Pantosteus santa-anæ* Snyder
(The tubercles in the upper lip are much more numerous in the *Pantosteus* than in
Catostomus macrocheilus.)

4. Lateral and apical (interradial) circuli about equally far apart, strictly transverse. 5
Apical circuli conspicuously more widely spaced than lateral. 6
5. Scale subcircular, about $4\frac{1}{2}$ mm. diameter, with about 4 to 6 apical, and 17 to 20 basal (no lateral) radii (Little South Fork, Cumberland River, Ky.; P. H. Kirsch), *Lagochila lacera* Jordan & Brayton
Scale smaller, rather more quadrate, with very prominent laterobasal angles; radii very strong, apical 4 to 6, basal 6 to 8 (Cherokee, Iowa; S. E. Meek). *Placopharynx duquesnii* (Le Sueur)
6. Basal radii very numerous, 12 in young scales, up to 20 or more in adult; center reticulated in latinucleate scales. *Catostomus commersonii* (Lacépède), including *C. teres* Mitchell
Basal radii less numerous. 7
7. Basal radii more than 12; scale hardly differing from *C. commersonii*, but interradian circuli more arched. *Erimyzon sucetta* (Lacépède)
Basal radii about 7 to 9 in normal scales. 8
8. With many incomplete apical radii. *Moxostoma cervinum* (Cope)
With at most one or two incomplete apical radii. *Minytrema melanops* (Rafinesque)

The scales of several of the above, but especially those of *Lagochila*, are quite of the type of *Chondrostoma*. It is evident that the scales of the American Catostomidae can be practically matched among the Palearctic and Oriental Cyprinidae, excepting only the western small-scaled group of *Pantosteus* and *Catostomus griseus, occidentalis*, etc. Even this exception is doubtful, for these smaller scales are certainly extremely like those of *Oreinus*, from Yunnan, Nepal, Assam, etc. It thus seems entirely impossible to find a scale character separating the Catostomidae from the Old World Cyprinidae. *Decactylus* Rafinesque, type *Decactylus commersonii* (Lacépède), or if Lacépède's fish is considered dubious, *Decactylus teres* (Mitchill), seems to be a valid genus, but *Catostomus occidentalis, macrocheilus*, etc., must be excluded from it.

COBITIDÆ. Loaches.

Subfamily COBITINÆ.

The scales of this subfamily have been discussed in Proceedings of the Biological Society of Washington, volume XXII, pages 205-206. The following genera are available for examination:

Cobitis Linnæus. T. c., p. 206 (*C. tænia*).

Misgurnus Lacépède. T. c., p. 206 (*M. fossilis, M. anguillicaudatus*).

Somileptes (Swainson) Bleeker. T. c., p. 206 (*Cobitis gongota*).

Lepidocephalichthys Bleeker. T. c., p. 206 (*L. berdmorei* and *L. guntea*).

Acanthopsis Van Hasselt. *A. chærorhynchus* (Bleeker) from Meetam, Tenasserim (Fea; B. M.) has scales which are much broader than long, with radii all around; transverse diameter less than half a millimeter. The scales are of the same general type as those of *Cobitis tænia*, and entirely different from the elongated scales of *Somileptes* and *Lepidocephalichthys*.

Subfamily HOMALOPTERINÆ. East Indian loaches.

For *Gastromyzon* and *Homaloptera* (pl. xxxiv, fig. 17) see Proceedings Biological Society of Washington, volume XXII, pages 206-207.

KNERIIDÆ.

Proceedings Biological Society of Washington, volume XXIII, page 113; Biological Bulletin, volume XX, plate v, figure 31. (*Kneria cameronensis* Boulenger). This family falls here in Jordan's list, but in his two-volume work no justification for this position is found. Boulenger, having examined the skeleton of *K. cameronensis*, places the family between Phractolamidae and Cromeriidae. Regan (1911) places it near to Chanidae, or milk fishes. It is an isolated type, and its scales are very peculiar.

Suborder GYMNOTI. Electric eels.

Dr. Max Ellis has in preparation a detailed paper on the scales of this group. He has very kindly allowed me to examine his series of slides in order to state the principal characters. Greatly to my surprise I find the scales to be quite different from those of the characinids known to me, but very similar

indeed to those of such cobitids as *Misgurnus* and *Lepidocephalichthys*. They may also be compared with the small-scaled catostomids, as *Pantosteus*, or in Cyprinidæ with *Oreinus*. This general type of scale, with radii all around and a sort of latticework pattern, is, I believe, really primitive, with characters not very distantly approaching those of the amphibian *Ichthyophis*. It appears, therefore, that the gymnotids are not "degraded characinids" (Boulenger), but rather specialized pre-characinids. The fully developed radial pattern is found in the small-scaled gymnotids, the scale being nearly circular (*Gymnotus carapo*), or elongated (*Sternopygus macrurus*), or transversely oval (*Hypopomus artedi*). In *Eigenmannia virescens* more than half the scale is without radii, and if they all disappeared we should have a scale not very unlike that of the characinid *Serrasalmo*.

In the larger scales of *Porotergus* and *Sternarchus* the radii are very fine and the basal ones converge to the middle line, curiously simulating the condition found in some Gadidæ, as *Urophycis*.

Order SCYPHOPHORI.

For the Mormyridæ (including Gymnarchidæ) see Smithsonian Miscellaneous Collections, volume 56, no. 3. In Jordan's list the Haplochitonidæ and Galaxiidæ appear as Scyphophori, but this reference is opposed to the treatment in the earlier part of the book, and according to Regan (1911) they are salmonoids.

Order HAPLOMI.

ESOCIDÆ. Pikes.

Esox (or *Lucius*) *lucius* from Toledo, Ohio (Rutter), has oblong scales about 3.5 mm. long and slightly over 2.5 wide; nucleus anterior to the middle; no apical radii, but two or three very strong basal radii or plicæ, ending between the large lobes of the basal margin. The circuli are dense, the apical ones distinct and transverse, with no approach whatever to any ctenoid structure. The base of the scale is nearly as in *Synodus*. (Pl. xxxv, fig. 20.)

UMBRIDÆ. Mud Minnows.

Umbra limi (Kirtland) from Milwaukee County, Wis. (Grænicher), has peculiar subquadrate or oblong scales, the largest about 3 mm. long, wholly unlike those of *Esox*. There are no radii, nor is the basal margin at all lobed. The very coarse circuli are essentially longitudinal, extending from one end of the scale to the other, but the innermost slant toward the middle line, meeting those of the opposite side at an extremely acute angle. In the largest scales the apical circuli are not angled in the middle, but normally arched, becoming transverse in the middle; the basal circuli in the same scales converge to two or three points, producing a transversely zigzag appearance. In *Kneria* the system of circuli is very much the same, though differing in detail. Much more noteworthy and surprising is the great resemblance in structure to the scales of *Urophycis regius*. So far as the scales go, *Umbra* and *Urophycis* might be imagined to belong to closely allied genera. Dr. Gill (Smiths. Misc. Coll., vol. 45, p. 297) has given a rather unsatisfactory figure of an *Umbra* scale.

PŒCILIDÆ. Killifishes. (Pl. xxxv, fig. 21, 22; pl. xxxvi, fig. 23.)

Scales broad, more or less semicircular, cycloid, with the nucleus apicad of middle and strong basal radii. No apical radii; circuli not, or not very, dense. *Tilapia* (Cichlidæ) has the same sort of scale, thus quite different from that of Pomacentridæ (*Eupomacentrus* and *Abudefduf* examined), which is ctenoid, of the ordinary Acanthopterygian type.^a Compared with *Esox* or *Lucius* the Pœciliid scale differs by its broad form (the scale of *Lucius* is longer than broad), numerous basal radii (two or three in

^a Many Cichlidæ have ctenoid scales, and no doubt *Tilapia* is secondarily, not primitively, cycloid; a parallel development to that of the Embioticidæ. In fact, it is not quite correct to say that *Tilapia* is cycloid, since extremely minute marginal teeth can be detected with the compound microscope.

Lucius), and much less dense circuli. On the other hand, the scale of *Dallia pectoralis* does not essentially differ from the smaller pœciliid scales, though the sculpture is less regular. Latinucleate scales are common in the pœciliid material examined.

The following rather unsatisfactory key is based on normal (not latinucleate) scales:

- Scales larger, more than 3 mm. across 1
- Scales smaller, less than 3 mm. across 4
- 1. Apicolateral outline a regular even curve, or without angles; nucleus a short distance apicad of middle; basal radii about 17, only about the 10 midmost complete.
 - Cyprinodon carpio* Günther. Tarpon Springs, Fla. (Evermann & Kendall).
 - Apicolateral outline evidently bent or angled, the apical margin thus separated from the lateral. . . 2
 - 2. Nucleus less than a third of length of scale from apex; apicolateral angles pronounced, but apical margin convex; basal radii about 13 to 16.
 - Gambusia puncticulata* Poey. San Antonio, Pinar del Rio, Cuba (Eigenmann & Riddle)
 - Nucleus more than a third of length of scale from apex. 3
 - 3. Scale larger, very broad (lat. pr. 6 mm.), apical margin hardly elevated.
 - Fundulus heteroclitus* (Linnaeus), Woods Hole, Mass.
 - Scale smaller, not so broad (lat. pr. 4 mm.) apical margin more elevated.
 - Mollienisia latipinna* Le Sueur, Gordon's Pass, Fla. (Henshall).
 - Differing from the above two in having the scale longer than broad.
 - Fundulus majalis* (Walbaum).
 - 4. Nucleus far above middle of scale; basal radii about 10 or 11.
 - Pecilia butleri*; Jordan; fish about 40 mm. long; Salina Cruz, Mexico (C. C. Deam).
 - Nucleus about middle of scale or even below. 5
 - 5. Scale subquadrate, with more or less evident anterolateral angles.
 - Fundulus diaphanus* (LeSueur), Osterville, Mass.
 - Scale broad, not subquadrate, without anterobasal angles. 6
 - 6. Scale less than 1½ mm. diameter. *Lucania parva* (Baird & Girard), Woods Hole, Mass.
 - Scale more than 1½ mm. diameter.
 - Gambusia affinis* (Baird & Girard), Myakka River, Florida (J. A. Henshall).

Dr. Max Ellis has kindly allowed me to examine scales of *Anableps anableps* (Linnaeus) the four-eyed fish, and *A. microlepis* Garman, which he collected at Georgetown, British Guiana. They are quite large, those of *A. anableps* much broader than long, with a width of about 8 mm., those of *A. microlepis* smaller, and not so broad. In all respects they are quite typical pœciliid scales, much like those of *Cyprinodon*, but with considerably denser lateral circuli.

Order XENOMI.

DALLIIDÆ. Alaska blackfish.

Dallia pectoralis Bean, from Nushagak, Alaska (Albatross collections) has small scales about 1½ mm. diameter, with coarse circuli and numerous (about 15) basal radii, the basal margin finely scalloped. There is nothing in these scales which might not be expected in the Pœciliidæ. Regan has recently proposed to include the Esocidæ, Umbridæ, and Dalliidæ in Haplomi and to recognize a new order, Microcyprini, for the Pœciliidæ and Amblyopsidæ. So far as the scales go, the following arrangement would seem natural.

- 1. Umbridæ.
- 2. A. Esocidæ.
 - B. a. Dalliidæ.
 - b. Pœciliidæ,

the last showing a close approach to the acanthopterygian type.

Order ACANTHOPTERI. Spiny-rayed fishes.

THE ACANTHOPTERYGIAN TYPE OF SCALE.

The serranid *Centropomus striatus* (Linnæus), the black sea bass, from Woods Hole, Mass., may be taken as a type for the definition of the acanthopterygian scale. This scale is more or less quadrate, with the nucleus subapical, the basal circuli fine and transverse, the basal radii strong, spreading out like a fan, and the apical area covered with fine dentiform structures which can be counted in rows obliquely or transversely, and on the margin form a series of fine teeth. The *Centropomus* scale described is atypical in one respect—the marginal teeth are truncate instead of pointed. The toothed or ctenoid feature appears to be derived from the longitudinal apical circuli which become modified and segmented, the terminal segments especially taking the form of teeth. It is this segmented arrangement which gives the apical area in acanthopterygians its special character, resembling very much the arrangement of bracts in the heads of some composite flowers. In the poeciliid scale we have a structure resembling much that of the acanthopterygians, but the ctenoid character wholly undeveloped; in some cichlids we attain a superficially similar condition, the ctenoid character having been lost.

At first sight the scales of the various acanthopterygian families Hæmulidæ, Lobotidæ, Serranidæ, Lutianidæ, Percidæ, Centrarchidæ, Anabantidæ, Sciaenidæ, Mullidæ, Polynemidæ, and Mugilidæ appear so much alike that classification seems extremely difficult. There are, however, some good distinctions visible on close comparison and brought out more or less in the following table. This does not apply to latinucleate or lateral line scales.



FIG. 8.—*Centropomus striatus* (Serranidæ). Ctenoid structures. Bureau of Fisheries.

- Basal margin broadly emarginate in middle, the basal radii (about 4 or 6 distinct) nearly parallel, converging toward the margin; teeth of apical margin very small, not different from the submarginal structures..... *Mugil curema* Cuvier & Valenciennes (Mugilidæ)
- Basal radii spreading..... 1
1. Middle of basal margin deeply emarginate; radii one in the middle, and usually three (closer together than the innermost to the middle one) on each side, not deeply impressed; apical modified area reaching nearly to nucleus; apical marginal teeth very small, sharp; subapical pattern composed of elements resembling phalanges, but grooved or bicarinate.^a
Polydactylus octonemus Girard (Polynemidæ)
- Basal margin deeply lobed between the five of six widely and often irregularly spaced basal radii; large scales with extremely fine circuli; modified marginal area not approaching nucleus; marginal teeth sharp; submarginal elements phalangiform, flattened, looking like bricks placed on end, without grooves or keels, though some of the basal ones may have broken vermiform markings. Surmulletts (Mullidæ)..... 2
- Not like the above (in *Perca* the basal margin is strongly lobed, but then the basal radii are regular and very deeply impressed, and the apical region is differentiated into two parts)..... 4
2. Subapical marginal elements longer, many about four times as long as broad.
Mullus auratus Jordan & Gilbert, Woods Hole, Mass.
- Subapical marginal elements shorter, none about four times as long as broad..... 3
3. Elements of apical area in 5 or 6 transverse rows (only two in latinucleate scales).
Upeneus dentatus Gill. Clarion Island (Albatross)
- Elements of apical area in 8 or 9 transverse rows.
Mulloidops samoensis Günther. Honolulu, Hawaii (Jordan & Evermann)
4. Apical area beset with linear, spine-like structures (the marginal teeth not differing), the lateral ones often continuous at base with the circuli; apical circuli very widely spaced, meeting at about a right angle above nucleus; basal radii about 15 (Anabantidæ).
Anabas scandens Linnæus. Lake Buhi, Philippine Islands
- Apical area not thus..... 5
5. Scales conspicuously longer than broad; margin with about 7 or 8 prominent teeth or projections, to the ends of which the basal framework of the scale is carried; apical area with much reddish brown pigment; scale suggestive of *Achirus*, but the subapical structure different.
Epinephelus niveatus (Cuvier & Valenciennes). Katama Bay, Mass. (Serranidæ)
- Apical margin with many teeth..... 6

^a In *Mugil* these structures are dentiform, like pointed scales, thus very different.

6. Marginal teeth truncate, often (except in *Micropogon*) broader at end than in middle. 7
Marginal teeth sharply or rather obtusely pointed. 12
7. Circuli above the nucleus broad and sublongitudinal, so that the nucleus and adjacent circuli suggest a section of an onion. 8
Circuli above the nucleus transverse (concentric) or (in *Orthopristis*) evanescent. 10
8. Scales much larger (about 8 mm. long and broad); elements of apical area with the median oblique rows about 12 or 13, but the inner ones poorly developed; basal radii about 9 or 10. *Centropistes striatus* (Linnaeus). Woods Hole, Mass. (Serranidæ)
Scales smaller (less than 4 mm. long), longer than broad; inner elements of apical area distinct (Serranidæ). 9
9. Scales 3 to nearly 4 mm. long. *Paralabrax maculatofasciatus* (Steindachner). Guaymas, Mexico (Albatross)
Scales $1\frac{1}{2}$ to $1\frac{2}{3}$ mm. long. *Paralabrax clathratus* (Girard). San Diego Bay, Cal. (Albatross)
10. Circuli above the nucleus lost, the surface finely roughened. *Orthopristis chalcus* (Günther). Guaymas or Clarion Island (Albatross). (Hæmulidæ)
Circuli above the nucleus distinct. 11
11. Scale larger, up to over 10 mm. broad; elements of apical area in middle about 16 in a longitudinal series. *Micropogon undulatus* (Linnaeus). (Sciænidæ)
Scale smaller; elements of apical area in middle 8 or less in a longitudinal series. *Leiostomus xanthurus* Lacépède. Florida. (Sciænidæ)
12. Apical teeth very short, for the most part hardly so long as their distance apart. 13
Apical teeth well developed. 14
13. Apical teeth more or less bifid at tip; sculpture of apical area strong. *Morone americana* (Gmelin), fish nearly 8 inches long. (Serranidæ)
Apical teeth not bifid; sculpture of apical area weak. *Micropterus salmoides* (Lacépède). Falmouth, Mass. (Centrarchidæ)
14. Scales large, colorless, very broad (a well developed one about 11 mm. broad and 8 long), often inequilateral; basal radii very numerous (about 40) and close together; elements of apical area longitudinally ridged or keeled. *Cynoscion regalis* (Bloch & Schneider). Woods Hole, Mass. (Sciænidæ)
Scales very large, quadrate, equilateral (a well developed one about 16 mm. long and $15\frac{1}{2}$ broad), orange-fulvous; basal radii very numerous (about 37, but many only in the peripheral area); circuli punctulate; submarginal elements of apical area much longer than broad. *Lobotes surinamensis* (Bloch). (Lobotidæ)
Scales smaller and otherwise different; many very small. 15
15. Base of scale very deeply crenate, many of the lobes as long as broad; basal radii 5 or 6; apical area with a marginal band in which the elements are very distinct, but mesad of this they are indistinct, the transition abrupt. *Perca flavescens* (Mitchill). Falmouth, Mass. (Percidæ)
Base of scale not thus deeply crenate. 16
16. Scales larger, fully 5 mm. long and broad; basal radii very numerous (about 28-32) and close together; basal circuli punctulate. *Roccus lineatus* (Bloch). Woods Hole, Mass. (Serranidæ)
Scale much smaller; basal radii less than 20. 17
17. Basal radii about 18. *Hypohomus spilatus* (Gilbert). Hector Creek, Kentucky. (Woolman). (Percidæ)
Basal radii usually less than 10 (9 to 11 in *Neomænis*). 18
18. Submarginal elements of apical area much longer than broad. 19
Submarginal elements of apical area mostly or all broader than long. 20
19. Lateral circuli strongly curving inward above. *Morone americana* (Gmelin), fish 3 inches long. (Serranidæ)
Lateral circuli (except the innermost) hardly curving inward above. *Neomænis analis* (Cuvier & Valenciennes). Katama Bay, Mass. (Lutianidæ)
20. Scales very small; apical teeth broad at base, rapidly tapering to very slender sharp points; basal radii 6 to 9. *Boleosoma nigrum* (Rafinesque). Osterville, Mass. (Percidæ)
Apical teeth conical, more regularly tapering. 21
21. Lateral circuli (except the innermost) directed obliquely outward above, so that if they were continued in a straight line below until they met, they would form a broad V; basal radii 7 to 8. *Brachydeuterus leuciscus* (Günther). San Juan Lagoon, Rio Ahoma, Mexico (Albatross). (Hæmulidæ)
Lateral circuli (except the innermost) directed upward above. 22
22. Submarginal elements of apical area appearing distinctly concave below (helmet-shaped); basal radii 8. 8
Hæmulon steindachneri (Jordan & Gilbert). Gulf of California (Albatross). (Hæmulidæ)

- Submarginal elements of apical area not appearing concave below..... 23
 23. Submarginal elements of apical area hat-shaped.
Cottogaster shumardi (Girard). Wabash River, Ind. (B. W. Evermann). (Percidæ)
 Submarginal elements of apical area quadrate.
Menticirrhus saxatilis (Bloch & Schneider). Woods Hole, Mass. (Sciaenidæ)

Suborder SYNENTOGNATH.

BELONIDÆ. Marine gars.

The houndfish, *Tylosurus acus* (Lacépède) has irregular elongate (broad) scales with conspicuous concentric circuli, but no radii whatever. They thus recall the scales of Salmonidæ.

EXOCEETIDÆ. Flying-fishes.

Cypsilurus heterurus (Rafinesque) has large broad thin scales, about 10 mm. broad and 8 long; nucleus a short distance below middle; circuli strong, concentric, in some scales much more widely spaced laterally, and then often angled; margin wholly cycloid; about 4 or 5 strong basal radii (more in latinucleate scales), none apical. Except for the presence of radii, this is very similar to *Tylosurus*. It seems also to lead toward the scombrid type.

HEMIRHAMPHIDÆ. Halfbeaks.

Hyporhamphus unifasciatus (Ranzani), from Woods Hole, Mass., has very broad scales, about 5 mm. long and 8, or slightly over, broad; apical margin broadly rounded; laterobasal corners rounded but evident; middle of base with a broad median lobe, which may be bilobed; basal radii two or three, widely diverging; nucleus near middle, but indistinct; apical field entirely covered with very fine transverse circuli, except a slender sculptureless submarginal band; basal field with transverse more widely spaced circuli, bending upwards and still more widely spaced in the lateral fields, and ultimately, when not reaching the margin, forming acute angles with the adjacent circuli of the apical field. The transverse dense apical circuli remind one of *Xystæma* (Gerridæ), but in *Xystæma* there is no sign of lateral angulation, and the apical marginal region is entirely different.

The scale of *Hyporhamphus* is evidently a further development, much more extreme, of the type of *Cypsilurus*. It also seems to point clearly in the direction of the scombrids.

SCOMBRESOCIDÆ. Sauries.

The billfish, *Scombrox saurus* (Walbaum) represents a still more extreme development along the lines of *Hyporhamphus*. The thin scale is about 5 mm. long and 8 broad, without angles or radii. The circuli are everywhere completely transverse, denser on the apical than the basal half, the two halves separated in some cases by more or less of an interval about the middle. At each extreme side is a thin zone, sculptureless except for a few irregular lines. The scales are of the same general type as those of the Scombridæ and Cheilodipteridæ.

So far as seen, the synentognathous families may be separated thus:

- Apical and basal circuli about the same..... 1
 Apical circuli transverse, denser than basal..... 2
 1. Radii absent..... Belonidæ
 Basal radii strong..... Exocetidæ
 2. Without radii..... Scombresocidæ
 With radii..... Hemirhamphidæ

If doubt should arise owing to the apical circuli of Scombresocidæ not being much denser than the basal, the family will still be easily recognized by the completely transverse character of the circuli, so that the effect of lateral angulation is lost. Dr. Jordan states that Regan (1911) recognizes an order Synentognathi, with one suborder for the belonids and scombresocids, and another for the hemirhamphids and exocetids. The scale characters would not have suggested this arrangement.

Suborder PERCESOCES.

ATHERINIDÆ. Silversides. (Pl. xxxvi, fig. 25.)

For a general account of the scales of this family, see Proceedings of the Biological Society of Washington, volume XXIII, pages 47-48. The genera *Kirtlandia* and *Menidia* are discussed, and the resemblance to the scombrids is noted. All the scales except *Kirtlandia* have distinct basal radii, with the lower margin usually scalloped; the laterobasal angles are distinct, and there are distinct apical radii in some forms, as *Chirostoma*. The following key separates the species before me:

Lateral and apical circuli alike and continuous, the circuli very widely spaced; scale very small, less than $1\frac{1}{2}$ mm. broad, strictly cycloid; no apical radii; basal radii well developed, about 5 or 6; laterobasal angles rectangular.

Atherinops regis Jenkins & Evermann. (Algodones Lagoon, Mexico; Albatross)

Lateral circuli strongly differentiated from apical, or the latter modified or partly suppressed. 1

1. Apical margin scalloped or lobulate. 2
Apical margin entire. 3

2. Scale much broader than long; basal margin undulate, with a single large lobe; apical margin irregularly lobed, with traces of radii; basal radii reduced to one or two broad folds, no true radii; apical field without sculpture, but across the middle of the scale, apicad of the regular circuli, is an area of very fine longitudinal lines, in the middle on the apical side breaking into very fine labyrinthiform markings. *Kirtlandia laciniata* (Swain). (Chesapeake Bay, Va.)

Scale little (sometimes not at all) broader than long; basal margin more or less angulate in the middle; apical margin finely irregularly scalloped, with evident though slender radii; basal radii about 7 to 10, well developed; lateral circuli very widely spaced, but apical field with extremely fine transverse circuli, which are much broken, and in the nuclear area mostly reduced to dots. *Chirostoma crystallinum* Jordan & Snyder. (Lake Chapala, Mexico; J. N. Rose)

3. Basal radii distinct; lateral circuli very widely spaced; apical circuli transverse, very dense, more or less broken, toward the nucleus reduced to granules; apical radii very slender, irregular, not always evident.

Menidia peninsulæ (Goode & Bean); *M. menidia* (Linnaeus); *M. notata* (Mitchill)

Of this series, *Chirostoma* is possibly the most primitive, but *Atherinops* stands apart and has the primitive character of continuous, uniform circuli in the lateral and apical regions. *Kirtlandia* seems much modified, but hardly from a *Menidia*-like basis. Probably *Atherinops* and its allies should form a distinct subfamily.

The scales of *Menidia notata* described in my paper cited above were not adult; other scales from the Bureau of Fisheries collection are about 3.5 mm. broad, with the apical margin subangulate or roof-like in profile.

MUGILIDÆ. Mulletts.

The white mullet, *Mugil curama* Cuvier & Valenciennes, from the collection at Woods Hole, has large rounded scales, with a straight, medially emarginate base; length about 9.5-10 mm; breadth 11-11.5; basal radii few, crowded about the middle of the scale; nucleus apicad of middle; lateral circuli coarser than basal; apical margin minutely ctenoid, the apical region with the minutely imbricated structure of typical ctenoid scales.

Here, then, we first meet with the typically ctenoid type of scale, as developed among the Acanthopterygians. The ctenoid scales of certain Characinidæ are of an entirely different character.

There is no evident connection between the scales of *Mugil* and those of the Atherinidæ.

SPHYRÆNIDÆ. Barracudas.

The scales of *Sphyræna* are very peculiar, and wholly unlike those of the Atherinidæ or Mullidæ. *S. picuda* Bloch & Schneider, from Tampa, Florida, has relatively large reddish scales, about 7 mm. long and a little over 6 broad, the lateral and basal margins gently convex, laterobasal corners obtuse, the apical region thin and without sculpture. The sculptured part of the scale has throughout extremely dense circuli, which, except in the upper lateral region, are interrupted by very numerous radii. The radii are very uniform, about 5 to 9 to a millimeter of the margin. The midmost circuli are not only divided into short sections by the radii, but the sections themselves are cut at intervals by very fine

lines, so as to seem segmented. In *S. borealis* DeKay, from Woods Hole, the colorless scales have a diameter of hardly $1\frac{1}{2}$ mm., and the fine radii, instead of continuously interrupting the circuli, are represented by series of minute round holes, which, however, coalesce in some places, producing a condition like that of the great barracuda, *S. picuda*. In the northern barracuda, *S. borealis*, the apical sculptureless area is very small or wanting. The sphyranid scale is very suggestive of that of *Gadus* and allied genera.

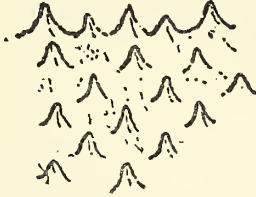


FIG. 9.—*Mugil* (Mugilidae). Ctenoid area. Bureau of Fisheries.

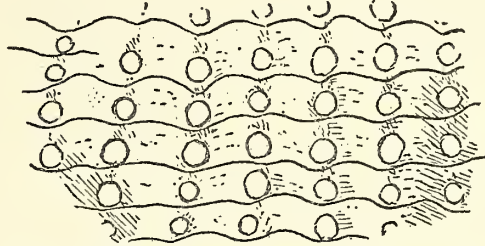


FIG. 10.—*Sphyræna borealis* (Sphyrenidae). Sculpture. Bureau of Fisheries. The transverse strands are circuli.

Jordan & Evermann state that the families Atherinidae, Mugilidae, and Sphyrenidae are closely related (Bulletin 47, U. S. National Museum, pt. 1, p. 788). They were associated together in the order Percosoces by Cope. Boulenger includes in Percosoces several other families, as Anabantidae, Stromateidae, Polynemidae, Scombresocidae, etc., stating that the group is perhaps only an artificial one, but "a gradual passage may be traced connecting the most aberrant types."

The scales would certainly suggest that the three families described above are not very closely related.

Suborder RHEGNOPTERI.

POLYNEMIDÆ. Threadfins.

Jordan states that the Polynemidae are allied to the Mugilidae, but differ from them and from all other fishes in the structure of the pectoral fin and its basal bones. In Boulenger's arrangement they go in the Percosoces, following the Mugilidae. In *Polydactylus octonemus* Girard the scale is quite

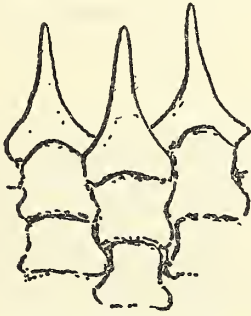


FIG. 11.—*Polydactylus* (Polynemidae). Apical teeth. Bureau of Fisheries.

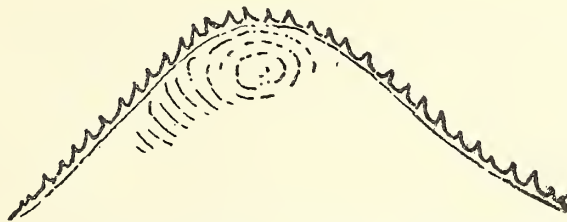


FIG. 12.—*Percopsis guttatus* (Percopsidae). Marginal teeth. Bureau of Fisheries.

typically Acanthopterygian, with ctenoid apical area, nucleus apicad of middle, and well-developed basal radii. The scale is nearly as in *Mugil*, having the same basal emargination, but differing in the spreading basal radii. The minute elements of the apical area are not as in *Mugil*, the submarginal ones being truncate instead of pointed.

Although there are differences, the scales would suggest that the Polynemidae are actually nearer to the Mugilidae than the latter to the Atherinidae or especially the Sphyrenidae.

Suborder SALMOPERCÆ. Trout perch.

PERCOPSIDÆ. Sand rollers.

The trout perch, *Percopsis guttatus* Agassiz, from East Okoboji Lake, Iowa (Evermann), has broad subtriangulate scales, with the apical margin forming two sides of the triangle, each side with about 17 sharp teeth. Nucleus very close to apex; circuli widely spaced; a slight tendency to basal plication, but no distinct radii. In the form of the apical region, with the nucleus very far apicad and the single row of sharp teeth, this reminds one of *Gobius* and its allies. In the Gobiidæ, however, the basal radii are very well formed and numerous.

Suborder BERYCOIDEA. Berycoid fishes.

BERYCIDÆ. Alfonsinos.

Jordan & Fowler say of this family: "Covered with ctenoid, or cycloid, foliate, or granular scales." I have from the United States National Museum scales of *Beryx splendens* Lowe (fish 21 inches long) from Japan. They are about 8 mm. long and 9.5-10.5 mm. broad, with the exposed part colorless and the covered pale yellowish red. The apical margin is thin and rather irregular, wholly without teeth; lateral margins concave; laterobasal corners very prominent; lower margin convex, irregularly subcrenulate; nucleus a short distance apicad of middle; basal circuli dense; weak basal folds in place of radii; broad apical region with growth lines but no circuli, and with scattered small round perforations. These perforations in the apical region sometimes have elevated margins, and in the region of the nucleus their place is taken by small sharp spines. Probably they arise as spines in every case, and the spines breaking off leave perforations. Jordan & Fowler state that the scales of *Beryx splendens* "are furnished with fine prickles, giving a somewhat rough touch." In *Beryx lineatus*, as figured by Sauvage, the prickles or spines of the apical region are large and dense. In either case, the arrangement parallels that found in species of *Macrurus*, and it is interesting in this connection to note that Regan some years ago suggested that the Gadoids might have come from the same stock which also gave rise to the Berycidæ. In *Caulolepis subulidens* Garman, as figured by Garman (Memoirs Museum Comparative Zoology, xxiv, 1899), the scales are extremely modified, but still have some of the spines or teeth.

TRACHICHYIDÆ. Deep-sea berycoids.

Garman, in the work just cited, figures the scale of *Trachichthys mento* Garman. It is transversely oval, without the laterobasal corners of *Beryx*, but it has a number of true berycoid spines in the subapical region. Boulenger refers the genus to Berycidæ.

HOLOCENTRIDÆ. Squirrel-fishes. (Pl. xxxvi, fig. 26.)

The scales of the Holocentridæ resemble in shape those of the Berycidæ, being broad, with prominent laterobasal angles. In every case, so far as known to me, the apical margin is armed with strong, straight, comb-like teeth. In some (especially *Myripristis murdjan*) the subapical region has spiniferous pits, of the same character as the spine-bearing holes of *Beryx*. The basal margin is straight or nearly so, except that in the middle it is thrown into one or more folds or lobes, indicative of the rudiments of a basal radial system. The scales are all broader than long, but those of *Flammeo* are not so conspicuously so as those of *Holocentrus*, and especially *Myripristis murdjan*; the last are larger than any of the others, about 8½ mm. long and 14½ broad, strongly reddish. The basal circuli in all are excessively fine, more so than in *Beryx splendens*. The species examined are as follows:

Myripristis murdjan (Forskål). Strong's I., Carolines (M. C. Z.).

Flammeo scythrops. Hawaii.

Flammeo sammara (Forskål). Hawaii.

Holocentrus diadema Lacépède. Hawaii.

Holocentrus laticeps Cuvier & Valenciennes. Kauai, Hawaii (M. C. Z.).

Holocentrus xantherythrus Jordan & Evermann. Hawaii.

Holocentrus microstoma Günther. Samoa.

The species of *Holocentrus* are so uniform in their characters that I can not construct a satisfactory key. There are, however, minor differences; e. g., the apical teeth of *H. xantherythrus* are much coarser than those of *H. laticeps*, and the basal radial folds are more prominent in *H. diadema* and *laticeps* than in the others.

Finding that *H. laticeps* was not recorded from the Hawaiian Islands, I asked Dr. Garman to look at the specimens (M. C. Z., 3440). This he kindly did, and reports that the identification is correct.

Sauvage, in his work on the fishes of Madagascar, has figured scales of *Myripristis seychellensis*, *M. pralinus*, *M. borbonicus*, *Holocentrus* (or *Holocentrum*) *spiniferus*, *H. diadema*, *H. leo* and *Holotrachys lima*. These show various peculiarities, but all confirm the essential uniformity of the holocentrid type, and indicate its general affinity with that of the Berycidae.

There is an evident resemblance between the holocentrid scale and that of *Aphredoderus*.

POLYMIXIIDÆ. Barbudos.

From the United States National Museum I have scales of *Polymixia japonica* Steindachner, from Japan (fish $7\frac{1}{4}$ inches long). They are very broad, with the same general shape and apical spines as *Holocentrus*, but the basal circuli are very much less dense, and the basal radial folds are very well marked, throwing the basal margin into numerous strong undulations. The laterobasal corners are less prominent than in the holocentrids, and the subapical region is without spines. Thus the Berycoidea, as regards their scales, form a sufficiently compact group, quite isolated from the groups standing on either side of it in the system.

Suborder PERCOMORPHI. Perciform fishes.

Superfamily SCOMBROIDEA. Mackerel-like fishes.

Broadly speaking, the families Scombridae, Carangidae, Cheilodipteridae, Stromateidae, Hemirhamphidae, Scombresocidae, Belonidae, and Exocoetidae may be ranged together (and apart from the percoid series) on their scales. Atherinidae show some resemblances also. The fishes are of course variously diverse in other characters.

SCOMBRIDÆ. Mackerels.

I have figured the scales of *Scomber* in Smithsonian Miscellaneous Collections, volume 56, no. 1. They are small and thin, broader than long, with the circuli transverse. In the common mackerel, *Scomber scombrus* (Linnaeus), from Woods Hole, the apical margin is more or less, but very irregularly, dentate, without the formation of definite structures like those on genuinely ctenoid scales. At these teeth the circuli are bent upward and angled, and this irregular waviness and angulation is seen here and there in the subapical field, indicating no doubt the teeth of an earlier stage. The fusiform area representing the nucleus is below the middle of the scale, and on each side of it the circuli are acutely angled. The circuli above the nucleus are somewhat denser than those below. The angulation of the lateral circuli in *S. scombrus* is like that of the basal ones in *Macrurus*.

In the bonito, *Sarda sarda* (Bloch), and the frigate mackerel, *Auxis thazard* (Lacépède), the scales are of the same general type, but still smaller and more degenerate, often practically without sculpture. Those of *Auxis* are often pointed laterally.

CARANGIDÆ. Cavallas, etc. (Pl. xxxvi, fig. 27.)

The jack, *Caranx hippos* (Linnaeus), has circular scales about $2\frac{1}{2}$ mm. diameter, with central nucleus and fine concentric circuli, not unlike some salmonid. There are no radii or marginal teeth. The inner circuli are variously angled laterally, and in the young the scales are transversely oval, and look just like those of *Scomber*. The carangid and scombrid scales are therefore very closely allied, although when adult appearing different.

CHEILODIPTERIDÆ. Bluefishes.

The bluefish, *Cheilodipterus saltatrix* (Linnaeus), from Onset, Mass., has scales slightly over 2 mm. long and about 3 broad; apex broadly rounded, base flattened, slightly and obtusely angled in the middle; laterobasal corners rounded but evident; no radii; circuli transverse apically and basally, more or less angulate laterally; nucleus below the middle. The lateral circuli are often angulate only on one side. The apical margin is thin, and when not worn off is irregularly dentate; the coarse circuli are not deflected or angled below these teeth, as they are in *Scomber*. This scale is entirely of the scombrid type.

STROMATEIDÆ. Butterfishes.

Gobiomorus gronovii (Gmelin), the Portuguese man-of-war fish, has feeble cycloid scales with widely spaced circuli which are more or less wavy. There are no radii. My material is perhaps immature. In the butterfish, *Poronotus triacanthus* (Peck), from Woods Hole, the scales are as in *Cheilodipterus* except that there are no signs of apical teeth, while the base often has one or two broad radial folds. The lateral circuli are angulate in most scales.

The pilot-fish, *Palinurichthys perciformis* (Mitchill), has quadrate scales about $4\frac{1}{2}$ mm. long and broad; laterobasal corners distinct; nucleus below the middle; circuli very distinct, the basal denser than the apical, the lateral vertical, parallel with the margin; four or five indistinct basal circuli. This scale is like that of the lake herrings, *Leucichthys*, and does not at all suggest that of the Scombridae and allies. Jordan & Evermann separated the Centrolophidae (*Centrolophus* and *Palinurichthys*) from Stromateidae, but Jordan has more recently made Stromateidae include both Centrolophidae and Nomeidae (*Gobiomorus*). The scales would strongly suggest that Centrolophidae, at least, are a valid family. There is a striking general resemblance between the scale of *Palinurichthys* and that of *Chirostoma crystallinum* Jordan & Snyder (Atherinidae), but the apical region of the *Chirostoma* scale is quite different.

PEMPHERIDÆ. Deep-water Catalufas.

Pempheris otaitensis (species perhaps wrongly determined) from the Red Sea (M. C. Z.), has scales which differ greatly in size on the same fish. The larger ones are about 4 mm. long and 6 broad; strictly cycloid, with circuli all around, transverse in the apical region; no apical radii; nucleus basad of middle; laterobasal corners rounded; about 15 strong basal radii, arranged fan-like, the basal margin strongly crenate. This scale, while very different from that of *Palinurichthys*, shows enough resemblance to suggest affinity.

Superfamily PERCOIDEA.

CENTRARCHIDÆ. Sunfishes and basses.

Mr. B. A. Bean very kindly sent me from the United States National Museum a very full set of centrarchid scales, with numbers only, so that I might classify them without any bias derived from a knowledge of their generic and specific identity. This I did, and afterwards the names and localities were supplied. The result was that I found the group to be on the whole a very compact one, the principal differences being found in the development of the apical teeth (the ctenoid feature), the density of the apical circuli, and the number of basal radii. The scales are quadrate or subquadrate in form, sometimes (*Micropterus dolomieu*) longer than broad, others (as *Lepomis gibbosus*) broader than long. No doubt the forms with well developed apical teeth are the most primitive (at least as regards their scales), the centrarchid type being originally ctenoid. It is interesting to note that *Archoplites interruptus* from San Francisco, the only fresh-water percoid west of the Rocky Mountains, has very strongly ctenoid scales, and the basal radii with an extremely minute beading. It is remarkable that in other forms the ctenoid margin is lost as the scale matures, thus:

- (1) *Ambloplites rupestris*, rock bass; young from Sodus Bay, N. Y., show a ctenoid V-shaped apical area, the apical margin with many sharp teeth; adults from Manchester, Va., show a perfectly entire apical margin, though (except in latinucleate scales) the V-shaped ctenoid patch is still visible as a sort of latticework pattern, failing below the margin. This is very different from the broad ctenoid area of *Archoplites*, the lower margin of which, in well-developed scales, is nearly straight.

- (2) *Micropterus salmoides*, large-mouth black bass; young from Sodus Bay, N. Y., show in most (but not all) scales a V-shaped ctenoid area, with teeth projecting slightly beyond the margin; scales of about the same age, from Falmouth, Mass., show the same, but are considerably narrower; adults from Bemus Point, N. Y., show a very broad ctenoid area, but the margin is toothless, or with extremely short and feeble projections. *M. dolomieu* is without ctenoid features at any age, though the apical circuli sometimes become sharply zigzag.

Scales of *Enneacanthus gloriosus*, from Washington, D. C., are strongly ctenoid, the ctenoid area very broad and the marginal teeth distinct; they differ conspicuously from those of *Archoplites* by their broader form, more minute apical teeth, and more numerous (usually 12 or 13) basal radii.

Chænobryttus gulosus, warmouth, from Washington, D. C., has variably ctenoid scales, the ctenoid area sometimes reduced to a very small patch. A hybrid between *C. gulosus* and *Lepomis gibbosus*, from the District of Columbia, has the ctenoid feature well developed, the area broad.

I could find nothing in the scales to justify the division of *Lepomis* into *Apomotis*, *Lepomis*, and *Eupomotis*. In the classification made without knowledge of the names, nearly all the species with intermediate characters—poorly developed but visible ctenoid features—fall in *Lepomis*, which is thus fairly compact on scale characters; but the so-called genera segregated from *Lepomis* are inextricably mixed. In the blue-gills *Lepomis pallidus* and *holbrookii* the apical margin is entire in some specimens, herein agreeing with the normal condition of *Pomoxis*. A disturbing feature is the great variability of some of the species, not only individual but racial. I give some examples:

- (1) *Micropterus salmoides* (Lacépède), large-mouth black bass. Scales from Falmouth, Mass., narrower than those from Sodus Bay, N. Y.
- (2) *Lepomis gibbosus* (Linnaeus), pumpkin-seed, from Washington, D. C., with the ctenoid area large, though the teeth are rudimentary; from Upper St. Croix River, Douglas County, Wisconsin (Grænicher), with widely spaced transverse apical circuli, and the ctenoid patch either wholly absent or reduced to a few marginal teeth of small size.
- (3) *Lepomis holbrookii* (Cuvier & Valenciennes), from the Carolinas, has the scale very broad (about 6½ mm. long and 8½ broad), with the ctenoid features distinct; other scales, also from the Carolinas, are much narrower and less ctenoid.
- (4) *Lepomis cyanellus* (Rafinesque), green sunfish, from Washington, D. C., and New Orleans, La., is conspicuously ctenoid when not latinucleate; from Woods Lake, near Greeley, Colorado (Warren), it is completely cycloid, with widely-spaced apical circuli.

It will be observed that these variations follow rather narrow lines, and the racial differences are of the same sort as the individual ones. It remains to be seen whether the apparent racial differences in scale characters, as in color and other features, are the direct result of environmental conditions, or indicate incipient species. It would seem likely enough that there are, in fact, a number of unrecognized subspecific types among the centrarchids, and the individual variability noted may be due in large part to the crossing of such types, which have remained distinct only as long as isolated.

The following systematic treatment mainly follows the lines of Jordan & Evermann's work:

Subfamily CENTRARCHINÆ.

Scales strongly ctenoid, the ctenoid patch very broad, though the teeth are very small; basal radii about 8 to 12; apical circuli quite dense *Centrarchus macropterus* (Lacépède) Dismal Swamp

Scales cycloid or with a small ctenoid patch; apical circuli dense, not differing from the lateral ones . . . 1.

Scales yellowish, about as long as broad; basal radii 6 to 12 *Pomoxis*

annularis Rafinesque, Neosho River, Mo., and *P. sparoides* (Lacépède) New Orleans, La.

Scales white, broader than long; basal radii 12 to 14 *P. sparoides*

Sodus Bay, N. Y., and St. Croix River, Douglas Co., Wis., the latter from Dr. Grænicher.

Are there northern and southern races of *P. sparoides*?

Subfamily LEPOMINÆ.

Tribe AMBLOPLITINI. (Pl. XXXVII, fig. 29, 30.)

Strictly cycloid, but the apical circuli widely spaced, and more or less strongly undulate or zigzag, as in *Gerrida*.....*Acantharchus pomotis* (Baird), Tarboro, N. C.
 Sharply ctenoid when young, but margin cycloid in adults.....*Ambloplites rupestris* (Rafinesque)
 With a small variously developed ctenoid area.....*Chænobryttus gulosus* (Cuvier & Valenciennes)
 Very strongly and coarsely ctenoid.....*Archoplites interruptus* (Girard)

Thus *Centrarchus* stands at the base of the *Centrarchinae*, and *Archoplites* at the base of the *Ambloplitini*.

Tribe LEPOMINI. (Pl. XXXVII, fig. 28.)

For the pharyngeal characters, see Bean & Weed, Proceedings United States National Museum, volume 40, pages 369-376. On the scale characters, *Enneacanthus* stands at the base of this series.

Scales strongly ctenoid.....*Enneacanthus gloriosus* (Holbrook)
 Scales moderately ctenoid, not so broad as those of *Enneacanthus*.
Mesogonistius chætodon (Baird) Trenton, N. J.
 Scales feebly ctenoid, rarely practically cycloid, with no generic difference from the last, except that they are usually less ctenoid and have fewer basal radii.....*Lepomis*

It seems impossible to make any key for the scales of the species of *Lepomis*; *L. gibbosus*, *cyanelus*, *punctatus*, *auritus* and some *euryorus* have the apical circuli more widely spaced than in the others. The species examined are *L. cyanelus*, *punctatus*, *symmetricus*, *auritus*, *megalotis*, *pallidus*, *albus*, *heros*, *holbrooki*, *euryorus*, *gibbosus*. The scale of *L. megalotis* (Lake Maxinkuckee, Ind.) is quite broad, with up to 12 basal radii, a larger number than is usual in the genus.

Subfamily MICROPTERINÆ. Black basses.

The genus *Micropterus* has been discussed above. The scales are the largest found in the *Centrarchidae*, but *Ambloplites* runs them close. *Ambloplites* differs from *Micropterus* in having the adult scales conspicuously broader than long, with denser apical circuli. It is a question whether *M. salmoides* should not be called *Aplites salmoides*, or *Aplites* Rafinesque at least used in a subgeneric sense.

The following arrangement of the centrarchid genera is suggested: *Centrarchus*, *Pomoxis*; *Aplites*, *Micropterus*; *Archoplites*, *Chænobryttus*, *Ambloplites*, *Acantharchus*; *Enneacanthus*, *Mesogonistius* *Lepomis*.

APHREDODERIDÆ. Pirate perches.

Subfamily APHREDODERINÆ.

Aphredoderus sayanus Gilliams. Houston, Tex. (Evermann). Scales about $2\frac{1}{3}$ mm. long and $1\frac{2}{3}$ broad, parallel-sided, with four very deep basal plications, the basal margin strongly scalloped; apical margin with a row of about 25 to 30 very long teeth, free only at apex; nucleus subapical; nuclear area with fine labyrinthiform markings; lateral circuli widely spaced, but with rudiments of others between them. This is very different from *Percopsis*, though agreeing in having a single row of apical teeth. Except for the ctenoid feature, there is a rather strong resemblance to *Lucius*. In the character of the ctenoid fringe, there is much resemblance to the ctenoid *Characinidae* of Africa. The ctenoid structures in *Percopsis* and *Aphredoderus* are quite different from those in *Perca*, but a fairly intermediate type occurs in *Pomacanthus arcuatus* (Linnæus).

Subfamily TRICHOPHANINÆ.

Trichophanes foliarum Cope, from the Miocene shales of Florissant, Colo., has been discussed and figured in the American Naturalist, volume XLII, pages 570-574. It is there regarded as the type of a distinct family, but I now believe that it deserves only subfamily rank. The scales have a subapical

nucleus, very coarse concentric circuli, and about 15 or more very long and strong sharp spines along the apical margin. Thus the scales agree in all essential features with those of *Aphredoderus*, and in their marginal teeth closely resemble *Xenochares* and *Distichodus* in the African characinid fauna.

The Aphredoderidæ seem quite out of place next to the Centrarchidæ. Jordan says of them: "Probably the most primitive of all living Percoid fishes, showing affinities with the Salmopercæ." *Aphredoderus* "agrees with the Berycoid fishes in scales and structure of the fins, and Boulenger places it with the Berycidæ." However, the resemblance to the berycoid scales is remote. In the Aphredoderidæ the apical teeth are articulated, as it were, on the margin, and in both the living and fossil fishes are movable. In the berycids they are instead rigid projections on the marginal area, into which they are basally prolonged.

Regan has recently referred the Aphredoderidæ to the Salmopercæ.

KUHLIIDÆ.

Kuhlia rupestris (Cuvier & Valenciennes) from Mauritius (M. C. Z. 5710) has rather large subquadrate scales, about 10 mm. long and broad, the latero-basal corners rectangular, and the lower margin nearly straight. The nucleus is about 6 mm. from the base; apical region typically ctenoid, of the usual Percoid type, the apical teeth numerous and sharp, the submarginal elements truncate (style of *Lagodon* in Sparidæ); basal radii delicate, about eleven. This agrees very well in general type with *Lucioperca*.

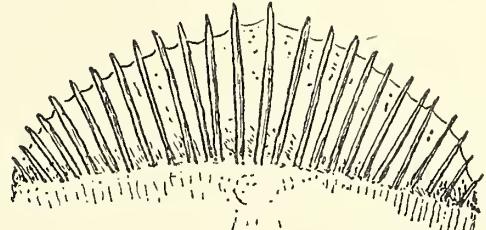


FIG. 13.—*Aphredoderus sayanus* (Aphredoderidæ). Marginal teeth. Bureau of Fisheries.

PERCIDÆ. Perches.

The typical percoid scale is subquadrate, ctenoid, with nucleus apicad of the middle, and strong basal radii. The American subfamilies are separated on the scales as follows:

- | | |
|--|--------------|
| Basal radii many or few (e. g., 20 in some <i>Hypohomus</i> , 6 in some <i>Boleosoma</i>); basal margin not very deeply crenate; submarginal apical elements short and broad..... | Etheostominæ |
| Basal radii few; submarginal apical elements quadrate; scales larger..... | 1 |
| 1. Basal margin very deeply crenate..... | Percinæ |
| Basal margin not very deeply crenate..... | Luciopercinæ |

In the Old World we find the following subfamilies:

- | | |
|---|------------------------------|
| Basal margin very deeply crenate or lobed; dorsal fins distinct; no canine teeth (<i>Perca</i>).... | Percinæ |
| Basal margin moderately crenate or lobed..... | 1 |
| 1. Submarginal apical elements short and broad; marginal teeth long (<i>Zingel</i>)..... | Etheostominæ |
| Submarginal apical elements longer, more quadrate; marginal teeth usually shorter..... | 2 |
| 2. Dorsal fins distinct (and other characters)..... | Luciopercinæ |
| Dorsal fins united (etc.)..... | Accrininæ (<i>Acerina</i>) |

I have not examined the genus *Percarina*.

In spite of the great development of Percidæ in North America, the group must surely have originated in the Old World, because (1) it is more varied in type there, and (2) it is more difficult to separate the European subfamilies than the American on their scales. However, the palæontological evidence indicates considerable antiquity for the percids both in Europe and America, and even if it is true that the living American subfamilies are of Old World origin, this does not prove anything regarding the history of the much older forms known as fossils.

The *Lucioperca-Acerina* type of scale is doubtless the primitive one in the family. It is difficult to find much difference between the scales of these genera, so different in other respects; but in *Acerina* the submarginal apical elements are more conspicuously broadened basally, approaching the condition

of the *Etheostominae* very noticeably, whereas in *Lucioperca* they are more nearly as in *Perca*. This character varies, however, in *Lucioperca*, and in *L. sandra* Cuvier & Valenciennes, from the Danube, the submarginal elements are quite short. *L. volgensis* Pallas, from Astrachan, has the submarginal elements conspicuously elongated. Boulenger unites the American *Stizostedion* with *Lucioperca*, and it is impossible to find any substantial difference in the scales. Curiously, the pike perch, *Stizostedion vitreum* (Mitchell) from Cedar Point, Toledo, Ohio, has the submarginal elements elongated as in *L. volgensis*; while *S. canadense* (C. H. Smith) from Big Sycamore Creek, Tenn., has them short as in *L. sandra*.

The species of *Acerina* examined are *A. cernua* Linnæus (Danube River and Switzerland) and *A. schræter* Linnæus. I can not separate them on the scales. *Acerina acerina* (*Perca acerina* Gmelin) I have not seen. The genus *Zingel* Cloquet includes *Z. zingel* Linnæus, *Z. asper* (Linnæus) and *Z. streber* (Siebold), unless we follow Jordan, and recognize a second genus (*Aspro* Cuvier & Valenciennes) for the second and third of these. I have *Z. zingel* and *Z. streber*. The scales of *Z. streber*, at least in my material, are smaller and shorter, otherwise there is no appreciable difference. Scales of *Z. zingel* (fish 10¼ inches long) are about 4 mm. long and 3½ broad, therefore much larger than any of the American *Etheostominae*, the largest of which are less than 2 mm. long. In the larger American scales (*Percini* and *Diplesion*) the basal radii are much stronger than in *Zingel*, and more parallel. Jordan remarks that *Zingel* is perhaps the ancestor of the entire group of *Etheostominae*.

Of *Perca* I have the three known species, European perch, *P. fluviatilis* Linnæus, from Sweden; American perch *P. flavescens* (Mitchell), from Lyndonville, Vt., and Falmouth, Mass.; *P. schrenkii* Kessl

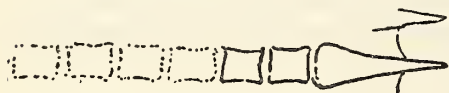


FIG. 14.—*Perca flavescens* (Percidae). Ctenoid structures. Bureau of Fisheries.

from Khuldscha. *P. fluviatilis* (fish 17 inches long) has large reddish scales, fully 10 mm. long, with six basal radii; basal margin deeply cut into long lobes; apical teeth short; subapical elements quadrate, but not elongated. *P. flavescens* (fish 6 inches long) has colorless scales about 4 mm. long; six basal radii; lobes of basal margin not so long; apical teeth short; subapical elements distinctly elongated. In *P. schrenkii* the scale is about the same size as that of *P. flavescens*, but longer, and broader above the middle than at the base, the reverse being conspicuously true of *P. flavescens*. The basal radii are three to six, and the lobes of the basal margin are shorter than in either of the other species. The apical marginal elements are distinctly elongated. Scales of *P. schrenkii* are readily known from those of *Lucioperca volgensis* by their peculiar form, narrowing below (basad), the shorter apical teeth, and the much more strongly crenate base.

It seems quite impossible to make a key to the genera or species of American darters, *Etheostominae*. I give a list of the species studied, with some notes.

Percina caprodes (Rafinesque), log perch. Chili, Ind. Scales about 1½ (some 1¾) mm. long, and about as broad; about 6 to 10 basal radii; apical teeth long.

Hadropterus phoxocephalus (Nelson). Durkey's Ferry, Wabash River, Ind.

H. macrocephalus (Cope). Obeyes River, Olympus, Tenn.

H. aspro (Cope & Jordan), black-sided darter. Upper Eel River, Allen Co., Ind.

H. guntheri (Eigenmann & Eigenmann). Cheyenne River, Valley City, N. Dak.

H. pellatus (Stauffer). Neuse River, Raleigh, N. C.

H. ouachitæ (Jordan & Gilbert). Marked Tree, Ark.

H. scierus Swain. Tippecanoe River, Marshland, Ind.

H. roanoka (Jordan & Jenkins). Neuse River, Raleigh, N. C. "Cotype."

H. maxinkuckiensis Evermann. Lake Maxinkuckee, Ind.

All have small scales with quite long apical teeth. They differ in size; thus *H. macrocephalus* has scales hardly over 1 mm. long, while *H. pellatus* has them fully 1.5 mm., the fishes in each case being 3 inches long. *H. pellatus* and *scierus* have scales of about the same size, but the apical teeth are distinctly longer in *scierus*.

Hypohomus spilatus (Gilbert). Hector Creek, Ky. (Woolman). Scales known from those of *Hadropterus* by the very large number of basal radii.

Cottogaster uranidea (Jordan & Gilbert). Vincennes, Ind.

C. copelandi (Jordan). Iowandi, Ky.

C. shumardi (Girard). Durkey's Ferry, Wabash River, Ind.; also Wabash River, Ind. (Evermann).

C. cheneyi Evermann & Kendall. Rackett River, N. Y. "Cotype." This genus has small scales like those of *Hadropterus*, with the basal radii only moderately numerous (e. g., 9 or 10), but the scales are conspicuously broader than long, averaging considerably shorter than those of *Hadropterus*.

Ulocentra stigmæa (Jordan). Obeys River, Olympus, Tenn.

U. gilberti Evermann & Thoburn. Walker's Ford, Clinch River, Tenn. "Cotype."

U. meadiæ Jordan & Evermann. Indian Creek, Tenn. "Cotype."

U. histrio (Jordan & Gilbert). Black Rock, Rock River, Ark.

U. simotera (Cope). Mount Verde, Tenn.

U. "probably new." Arnwine Creek, Athens, Tenn. $2\frac{3}{4}$ inches long.

Ulocentra has broad scales like those of *Cottogaster*, but the basal radii are more numerous (generally about 12), and the apical teeth are shorter, usually very short. *U. stigmæa* has very broad scales, some almost twice as broad as long, whereas in *U. gilberti* they are mostly not greatly broader than long.

Diplesion blennioides (Rafinesque), green-sided darter. Murfreesboro, Tenn., 5 inches long. Scales $1\frac{1}{2}$ mm. long and broad, with long apical teeth and about a dozen basal radii. The scales are larger than those of *Ulocentra*, *Cottogaster*, etc., but so is the fish. I can not satisfactorily distinguish *Diplesion* scales from those of *Percina*.

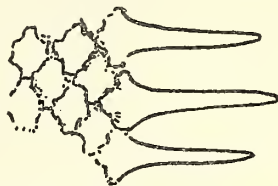


FIG. 15.—*Cottogaster shumardi* (Percidæ). Ctenoid structures. Bureau of Fisheries.

Boleosoma longimanus (Jordan). Lexington, Va.

B. podostemone (Jordan & Jenkins). Roanoke River, Va. "Cotype."

B. nigrum (Rafinesque). Osterville, Mass., and Columbia City, Ind.

In this genus the scales are broader than long, with about a dozen basal radii.

Crystallaria asprella (Jordan). Wabash River, Ind. 3 inches long; extremely small, rather broad scales, with long apical teeth.

Ammocrypta pellucida (Baird), sand darter. Adamsboro, Ind. 3 inches long.

A. beanii Jordan. Greenville, Ala. $2\frac{3}{4}$ inches long. The scales of this genus are also extremely minute, almost rudimentary.

Ioa vitrea (Cope). Raleigh, N. C. Scales minute, with long apical teeth; the principal character is found in the very widely spaced lateral circuli. The last three genera are the weakest scaled in the family.

Etheostoma. In this large genus the scales are of the same type as those of related genera, with pigment spots along the bases of the apical teeth, such as are found in other American Etheostominae, in *Zingel*, and even in *Acerina cernua*. The basal radii vary from 9 (*zonale*, *flabellare*) to 16 (some *pottsii*, *juliae*, and *iowæ*). In some species the scales average about as broad as long (*punctulatum*), in others they are conspicuously broader than long (*juliae*, *pottsii*), but in no case are they longer than broad, if we take scales from the middle of the side and measure only to the bases of the apical teeth. In some the scales are comparatively large (*variatum*), in others very small (*flabellare*). After measuring what seemed to be fair average scales of each species, I have thrown my results into the following key, but it must be clearly understood that while it is indicative of general tendencies or types, it is not at all reliable for the determination of the species.

The following abbreviations are used: long., lat., length and breadth; ap., length of longer apical teeth; b. r., number of basal radii; measurements all in microns, except the length of the fish.

- A. Length of scale less than 800.
 - a. Breadth of scale same as length.
 - E. flabellare* Rafinesque, fan-tailed darter (1 inch). Cumberland Gap, Tenn.; long. and lat. 590; lateral radii very widely spaced; 9 b. r.
 - E. punctulatum* (Agassiz) (1 inch). Marshfield, Ind.; long. and lat. 655; ap. 95; 10 b. r.
 - b. Breadth of scale much greater than length.
 - i. Scale very broad; pigment spots along margin light brown.
 - E. lepidum* (Baird & Girard) (1½ inch). New Braunfels, Tex.; long. 770, lat. 1150; 12-14 b. r.
 - ii. Scale moderately broad.
 - E. australe* Jordan. (1½ inch). Chihuahua, Mexico; very widely spaced circuli around nucleus; long. 775, lat. 935; ap. 95; 12 b. r.
 - E. camurum* (Cope) blue-breasted darter (2¾ inches). Marshland, Ind.; long. 705, lat. 880; ap. 95; 10 b. r.
 - E. tippecanoe* Jordan & Evermann (2 inches). Marshland, Ind.; long. 750, lat. 865; 9-12 b. r.
- B. Length of scale 800 to 1,040.
 - a. Scale about as broad as long.
 - E. cragini* Gilbert (1 inch). Garden City, Kansas; "cotype"; long. 815, lat. 830; ap. 95; 12 b. r.
 - E. jessiae* (Jordan & Brayton). Long. 1040, lat. 1055; ap. 145; 11-14 b. r.
 - E. whippitii* (Girard). (1½ inch). Kaimishi, I. T.; long. and lat. 800; 10-11 b. r.
 - b. scale evidently broader than long.
 - i. Basal radii 9.
 - E. zonale* (Cope) (1¾ inch). Cumberland Gap, Tenn.; long. 990, lat. 1090.
 - ii. Basal radii more than 10.
 - E. iowæ* Jordan & Meek. Creighton, Nebr.; long. 800, lat. 1040; ap. 80; 14-16 b. r.
 - E. obeyense* Kirsch (1¼ inch). Cumberland River, Wayne County, Ky.; long. 865, lat. 945; ap. 95; 11-13 b. r.
 - E. pottsii* (Girard). (1¾ inch). Chihuahua, Mexico; long. 960, lat. 1250; 15-16 b. r.
 - E. juliae* Meek. Springfield, Mo.; long. 1040, lat. 1295; 13-16 b. r.
 - E. boreale* (Jordan) (2¼ inch). Michigamme, Mich.; long. 925, lat. 1010 (another, long. 880, lat. 925); 12-14 b. r.
- C. length of scale over 1040.
 - a. Length of scale 1490, breadth the same.
 - E. variatum* Kirtland (2 inches). Blue River, Wyandotte Cave, Ind.; 11 b. r.
 - b. Length of scale not over 1330.
 - E. swannanoa* Jordan & Evermann (1½ inch). Black Mountain, N. C.; long. 1055, lat. 1280; 10-13 b. r.
 - E. squamiceps* Jordan (1½ inch). Murfreesboro, Tenn.; circuli around nucleus not very widely spaced; long. 1310, lat. 1375; ap. 72; 14 b. r.
 - E. jordani* Gilbert (2 inches). Oxford, Ala.; "cotype"; circuli around nucleus very widely spaced; long. 1170, lat. 1360; ap. 110; 9-12 b. r.
 - E. cinereum* Storer (3½ inches). Olympus, Tenn.; long. 1330, lat. 1345; ap. 128; 12 b. r.
 - E. coeruleum* Storer, blue darter. (1½ inch). Neosho, Mo.; long. 1120, lat. 1440; ap. 145; 11-15 b. r.
 - E. rufilineatus* (Cope) (2¾ inches). Knoxville, Tenn.; long. 1150, lat. 1200; ap. 145; 13 b. r.

It will be observed that there is very little correspondence between this arrangement and the subgenera recognized by authors. It is certain that the scales are of very minor value in the taxonomy of this group, and no doubt individual variation oversteps most of the limits suggested by my data. At the same time there are good average differences between several of the species; thus, when we compare the species, *E. pottsii* and *E. australe*, both from Chihuahua, it is evident that *pottsii* has larger and broader scales, and the difference is greater than can be accounted for by the somewhat larger size of the fish. It is probable that if statistical studies are made of numerous scales, some help will be obtained for the separation of closely allied species.

Psychromaster tuscumbia (Gilbert & Swain). Tuscumbia, Ala. Scales broader than long, not differing from those of *Etheostoma*.

Boleichthys fusiformis (Girard). St. Francisco River, Ark. Scales broader than long, like those of *Eltheostoma*, with prominent rectangular laterobasal corners; basal radii about 12 to 14.

Microperca punctulata Putnam. Lake Maxinkuckee, Ind. Scales very small, conspicuously broader than long (length about $765\ \mu$, breadth 1040); about 11 to 14 basal radii. Easily known from *Boleichthys* scales by the smaller size and obtuse laterobasal corners.

M. fonticola (Jordan & Gilbert). San Marcos, Tex. Scales like those of *M. punctulata*.

For the North American percid scales described above I am indebted to the Bureau of Fisheries, and for the European species to the National Museum, in each case through Dr. H. M. Smith.

In general, the scales of the Percidæ are quite distinct from those of the Centrarchidæ, though of the same essential character. The scales of the two families approach in such genera as *Archoplites* and *Lucioperca* (*L. sandra*), but in the *Archoplites* the nucleus is not so far apicad as in the other.

THE VALIDITY OF *BOLEOSOMA OLMSTEDI* (STORER), AS INDICATED BY ITS SCALES.

BY T. D. A. COCKERELL AND MARY ESTHER ELDER.

We recently received from the Bureau of Fisheries some scales of *Boleosoma olmstedii* (Storer), a form which has been treated as a subspecies of *B. nigrum*, but which Dr. W. C. Kendall believes to be a valid species. It was suggested that perhaps the scales might

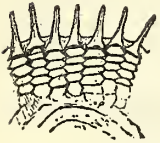


FIG. 16.—*Boleosoma nigrum*. Apical margin.

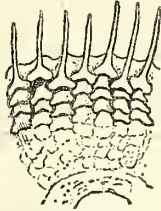


FIG. 17.—*Boleosoma podostemone*. Apical margin.



FIG. 18.—*Boleosoma olmstedii*. Apical margin. From specimen $3\frac{1}{16}$ inches long.

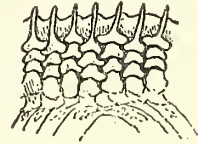


FIG. 19.—*Boleosoma olmstedii*. Apical margin. From specimen $1\frac{5}{8}$ inches long.

afford characters which would throw light on the question of the distinctness of *B. olmstedii*. We hardly expected positive results, on account of the undoubted affinity of the fishes, but a study of the material shows that, at least so far as our material goes, the scales of *B. nigrum* and *olmstedii* are readily separable. The observed difference can not well be a matter of age, as *olmstedii* scales were examined from fishes $1\frac{5}{8}$ inch and $3\frac{1}{16}$ inches, respectively, while the *B. nigrum* scales came from a fish $2\frac{1}{4}$ inches long. We also took occasion to compare scales of *B. podostemone* (cotype fish, $1\frac{3}{4}$ inches long), and found good characters to distinguish them from those of the others. The scales of the three may be diagnosed as follows:

- (1) *Boleosoma nigrum* (Rafinesque). Columbus City, Ind. Apical teeth rather long, the greater part free from the marginal membrane; subapical elements below the teeth transversely elongated, and usually in four rows.
- (2) *Boleosoma podostemone* (Jordan & Jenkins). Roanoke River, Va. Apical teeth very long, the greater part free from the marginal membrane; subapical elements below the teeth in two or three distinct rows, subtriangular in form.
- (3) *Boleosoma olmstedii* (Storer). Palmouth, Mass. Apical teeth moderate, less than half free from the marginal membrane; subapical elements below the teeth in two or three distinct rows, subtriangular.

APOGONIDÆ. Cardinal fishes.

In *Apogonichthys pomaræ* Steindachner from the Society Islands (M. C. Z. 9698), the reddish scales are much broader than long, length about $4\frac{1}{2}$, breadth about $5\frac{1}{4}$ mm.; general character percoid; 12 to 16 basal radii; laterobasal corners obtuse; lateral circuli numerous, oblique, running to the margin; apical teeth moderate; submarginal elements longer than broad, emarginate basally. Differs at once from *Lucioperca*, *Centropristes*, etc., by the oblique lateral circuli. The beginning of this obliquity is seen in *Percichthys*.

SERRANIDÆ. Sea basses. (Pl. XXXVII, fig. 32.)

The North American genera examined can be divided into subfamilies as follows:

Serraninæ (*Paralabrax*, *Centropristes*). Apical marginal spines truncate.

Epinephelinæ (*Epinephelus*). Apical marginal spines obtusely pointed, margined. Scales much longer than broad.

Moroninæ (*Morone*, *Roccus*). Apical marginal spines pointed or (adult *Morone*) minutely bifid at tip. *Roccus* is easily separated from *Morone* by the very numerous basal radii.

Another subfamily (*Percichthyinæ*) must be recognized for the freshwater genus *Percichthys* Girard, in which the adult scales are longer than broad, parallel-sided, with the broadly rounded apical margin entire, although there is a submarginal ctenoid patch, beset with spines.

Still another subfamily (*Plesiopinæ*) must contain *Plesiops* Cuvier, of which I have *P. corallicola* from the Ebon Islands (M. C. Z., 2473). The scale is 7 mm. long and $6\frac{1}{2}$ broad, the exposed part covered with dark purplish skin. Laterobasal angles obtuse; nucleus in the submarginal apical region, and from it radiate about 15 long basal radii; lateral circuli dense, slightly oblique; apical marginal teeth slender, more or less obtuse or truncate at end; subapical elements narrow and elongate. This is nearer to *Centropristes* than to any of the other scales cited above. A lateral line scale of *P. corallicola* is curiously different, with the nucleus much further down, and having strong apical as well as basal radii. Boulenger makes *P. corallicola* a synonym of *P. nigricans* (Ruppell).

Scales of *Aulacocephalus schlegelii* Günther (*A. temminckii* Bleeker) are figured by Sauvage in his work on the fishes of Madagascar. They somewhat approach those of *Epinephelus*.

Subfamily PERCICHTHYINÆ. The truchas.

My material of this group is from the United States National Museum.

Percosoma melanops (Girard). Santiago, Chile; $4\frac{3}{4}$ inches long. Scales reddish, about 3 mm. long and 2 broad; parallel-sided, with the laterobasal corners more or less projecting downwards; nucleus about 2 mm. from base; 6 to 9 basal radii; lateral circuli coarse, somewhat oblique; ctenoid patch very variable in size, with long narrow elements, some of which occasionally project as spines over the margin.

Percichthys trucha (Cuvier & Valenciennes). South America; $12\frac{1}{4}$ inches long. Scales reddish, the larger ones about $5\frac{1}{4}$ mm. long and $4\frac{3}{4}$ broad; nucleus about 3 mm. from base; basal margin slightly convex, delicately crenate; apical field as in *Percosoma*. In latinucleate scales there is no ctenoid patch, and the widely spaced apical circuli run right across, parallel with the broadly rounded margin.

A young fish, $5\frac{1}{4}$ inches long, from Argentina, has scales less than 2 mm. long, but still without projecting apical spines.

Although this fish is closely allied to *Percosoma*, the latter is readily separated by the long and narrow scales.

Percichthys chilensis (Girard). Santiago, Chile; $7\frac{3}{4}$ inches long. Boulenger makes this a synonym of *P. trucha*, and the scales seem the same, though the basal radii may average somewhat less.

Subfamily SERRANINÆ. Sea basses. (Pl. XXXVII, fig. 31.)

The following have been examined:

Centropristes striatus (Linnæus), black sea bass. Woods Hole, Mass. Scales subquadrate, about 8 mm. long and broad; ctenoid area very beautifully developed; apical teeth truncate and often broadened at base; nucleus subapical; basal radii 9 or 10; lateral circuli running parallel with margin.

Paralabrax maculofasciatus (Steindachner), spotted cabrilla. Guaymas, Mexico (Albatross). Scales about 4 mm. long and $2\frac{3}{4}$ broad, the long, parallel-sided form very different from that of *Centropristes*; basal radii 8 to 11.



FIG. 20.—*Epinephelus niveatus* (Serranidæ). Ctenoid structures. Bureau of Fisheries.

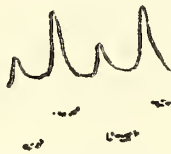


FIG. 21.—*Morone americana* (Serranidæ). Ctenoid structures. Bureau of Fisheries.

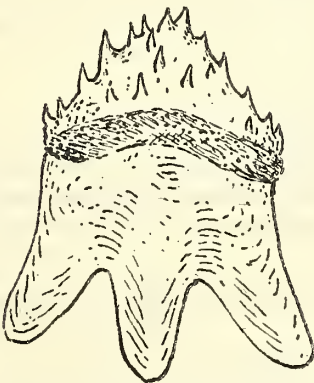
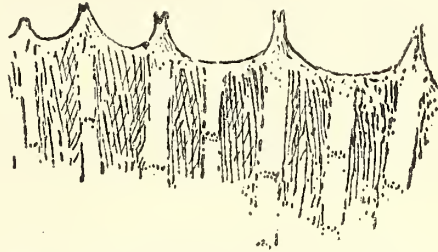


FIG. 22.—*Priacanthus* (Priacanthidæ). Bureau of Fisheries.

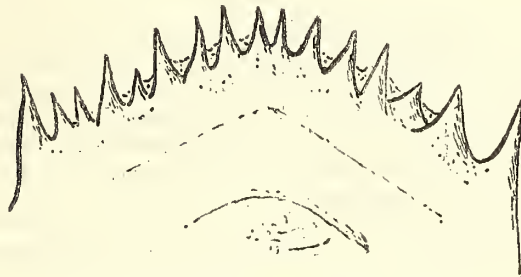


FIG. 23.—*Pseudopriacanthus altus* (Priacanthidæ). Bureau of Fisheries.

Paralabrax clathratus (Girard), cabrilla. San Diego Bay (Albatross). Scales similar, but smaller, and somewhat broader in proportion to their length. In both species of *Paralabrax* the scales are white; the finely mottled skin has the pigment light ferruginous in *P. maculofasciatus*, purplish-brown in *P. clathratus*.

Subfamily EPHINEPHELINÆ. Groupers.

Epinephelus niveatus (Cuvier & Valenciennes), snowy grouper, from Katama Bay, has scales which remind one of *Paralabrax*, but the basal radii are only 4 to 6, and the apical area is quite different, with the spines much reduced in number, but larger.

Subfamily MORONINÆ. White perches.

The characters of *Roccus* and *Morone* are given in the table of Acanthopterygian scales on an earlier page.

LOBOTIDÆ. Flashers.

The flasher, *Lobotes surinamensis* (Bloch) has large subquadrate reddish scales, which resemble those of *Roccus* in the very numerous basal radii. Other characters are given in the table just cited.

PRIACANTHIDÆ. Catalufas.

Two subfamilies may be distinguished as follows:

Priacanthinæ (*Priacanthus*). Scales very strongly trilobed at base: apex produced, with irregularly placed teeth.

Pseudopriacanthinæ (*Pseudopriacanthus*). Scales quadrate (the apical margin produced to an obtuse angle), the base not at all trilobed, but its middle third crenate from the 5 or 6 basal radii; marginal teeth sharp and irregular, but not so irregular as in *Priacanthus*.

All the specimens examined are from Woods Hole, Mass. The *Pseudopriacanthus* is *P. altus* (Gill). The *Priacanthus* is presumably *P. arenatus* Cuvier & Valenciennes, with which it agrees in fin rays, color of fins, etc., but it has a large serrate preopercular spine, as in *P. cruentatus* (Lacépède).

LUTIANIDÆ. Snappers.

The scale of the gray snapper, *Neomænis griseus* (Linnæus), from Tampa, Fla., has been figured in Proceedings of the Biological Society of Washington, volume XXIII, page 91. The mutton fish, *N. analis* (Cuvier & Valenciennes) is included in the table of Acanthopterygian scales above. The scale of *N. griseus* figured was much worn, and had lost the apical teeth, but the figure shows well the numerous basal radii, the lateral circuli running parallel with the margin, etc.

HÆMULIDÆ. Grunts. (Pl. XXXVII, fig. 33.)

In the pigfishes, *Orthopristis*, the marginal teeth are truncate; in the grunts, *Hæmulon*, and the burritos, *Brachydeuterus*, they are pointed. From these and other characters perhaps two subfamilies (Orthopristinæ and Hæmulinæ) may be indicated. Jordan & Evermann say of the Hæmulidæ: "The group is very close to the Lutianidæ on the one hand and to the Sparidæ on the other, while some of its members show affinities with some Sciænidæ and Serranidæ." In its scales *Orthopristis* resembles some Sciænidæ, as the croakers *Micropogon*.

The scale of *Anisotremus virginicus* (Linnæus) is figured in Proceedings of the Biological Society of Washington, volume XXIII, page 92.

SPARIDÆ. Porgies.

I have examined scup, *Stenotomus chrysops* (Linnæus) from Woods Hole, Mass., and pinfish, *Lagodon rhomboides* (Linnæus). Both have large scales, those of *Lagodon* quadrate, about as broad as long, those of *Stenotomus* much broader than long. The broad apical field has the usual Acanthopterygian sculpture feebly indicated, but only the margin is distinctly sculptured, with the well-formed elements in two (*Stenotomus*) or three (*Lagodon*) rows. This condition leads in the direction of that found in the Gerridæ. The basal radii are 12 in *Lagodon*, 13 or fewer in *Stenotomus*. The apical structure is nearly as in the coral fishes, Pomacentridæ, while both resemble the surmullets, Mullidæ. The scale of *Lethrinus*, as figured by Günther, has very well-developed sculpture in the apical field, with 13 or 14 rows of minute teeth.

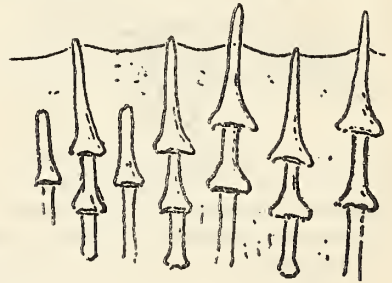


FIG. 24.—*Neomænis analis* (Lutianidæ).
Bureau of Fisheries.

In *Box vulgaris* (Vienna Museum; M. C. Z.) the scales are about $3\frac{1}{4}$ mm. long and $5\frac{1}{4}$ broad, with the nucleus central and about 10 widely spreading basal radial folds. This is much like *Stenotomus*, differing in the less apical nucleus; the sloping sides, making the lower margin the broadest part; the broad apical region with the small quadrate elements distinct over the greater part, with no marked difference between the marginal and submarginal ones; and the much more oblique lateral circuli. (Pl. XXXVIII, fig. 34.)

Dr. G. A. Boulenger kindly collected for me scales of *Dentex vulgaris* Cuvier, from a fish 2 feet 10 inches long, in the Grimsby Market. The scales vary very much in size and form; a large one is about 21 mm. long and 27 broad; an unusually broad one is about 13 mm. long and 21 broad; another is $15\frac{1}{2}$ long and 18 broad. These all come from the side of the fish. The circuli are excessively fine, and the lateral ones are little oblique, whereas in *Box* they are extremely oblique, reaching the margin at a large angle. The basal radial system is variably and often poorly developed, and the radii are not very numerous. The apical margin appears cycloid, but the apical field has a fine half obliterated honey-comb-like

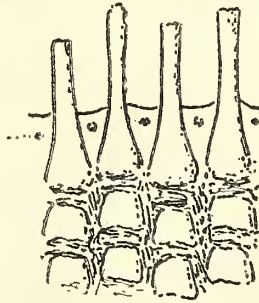


FIG. 25.—*Orthopristis chalcus* (Hæmulidæ). Ctenoid structures. The spots between the teeth are ferruginous pigment spots. Bureau of Fisheries.

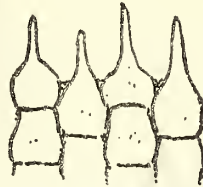


FIG. 26.—*Stenotomus chrysops* (Sparidæ). Ctenoid structures. Bureau of Fisheries.

structure representing the ctenoid patch. Curiously, the skin over the apical field is marked with a very distinct network of polygonal cells, corresponding to the structure beneath. The nucleus is apical of the middle.

In Dr. A. S. Woodward's Catalogue of Fossil Fishes (1901), and in earlier works, *Dentex* appears among the Percidæ (sens. lat.). Dr. Woodward states that *Dentex*, *Gerres*, etc., are intermediate between the Percidæ and Sparidæ.

MÆNIDÆ. Picarelæ. (Pl. XXXVIII, fig. 35.)

I have the scales of an undetermined species of *Smaris* (*Spicara*) from Trieste (M. C. Z., 10436). They are about $2\frac{1}{2}$ mm. long and $3\frac{2}{3}$ broad; nucleus a little above the middle; about 10 strong widely spreading basal radii; sides sloping, so that the base is much the widest part; lateral circuli extremely oblique, but wanting in upper lateral region; apical margin strongly angled in the middle; apical marginal teeth sharp, and below them about two rows of broad subquadrate elements, below which the apical field is almost without sculpture.

This may be regarded as an extreme development of the type of *Box*. The oblique lateral circuli also suggest *Apogonichthys*, which is, however, very different in the apical region.

GERRIDÆ. Mojarras.

The "broad shad," *Xystama cinereum* (Walbaum), from La Paz Harbor (Albatross) has transversely oval or oblong scales about 6 mm. long and 7 broad, the laterobasal corners rounded, and the basal radii few (about 5) and more or less irregularly placed. The lower margin is only feebly crenate. The thin apical field shows rudiments of the usual ctenoid structures of Acanthopterygians, reduced to

irregular transverse lines and small marginal denticulations. The lateral circuli are transverse, entirely in the manner of a clupeid. This last character is remarkable; a certain approach to it is found in *Stenotomus* (Sparidæ), in which the upper lateral circuli are obliquely directed outward, pointing to the anterolateral angles.

The scales of the silver jenny, *Eucinostomus gula* (Cuvier & Valenciennes), from Rio Grande do Sul, Brazil (M. C. Z., 16452) are so exactly like those of *X. cinereum* that I am at a loss to describe any difference. Scales of *E. gula* from Tampa, Fla., received from Dr. Grænicier, differ by having the apical field almost entirely covered with transverse circuli (not so dense as those elsewhere), and the ctenoid patch hardly indicated by even a rudiment. It is possible that northern and southern races of *E. gula* exist? (Pl. XXXVIII, fig. 36.)

KYPHOSIDÆ. Chopas.

The "chopa blanca" or Bermuda chub, *Kyphosus sectatrix* (Linnæus) from Menemsha Bight, Mass., shows a modified type of acanthopterygian scale, with a thickened band with hyaline dots across the middle, and the apical area having a grooved appearance. There are two rows of distinct elements on

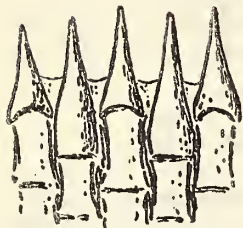


FIG. 27.—*Lagodon rhomboides* (Sparidæ). Ctenoid structures. Bureau of Fisheries.



FIG. 28.—*Kyphosus sectatrix* (Kypnosidæ). Apical teeth. Bureau of Fisheries.

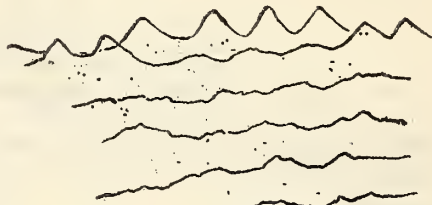


FIG. 29.—*Xystæma cinereum* (Gerridæ). Apical sculpture. Bureau of Fisheries.

the apical margin, the outermost ending in sharp teeth, and all triangular at base, approaching the condition found in *Neomænis* (Lutianidæ) and *Chatodon* (Chætodontidæ). The scales are broad-quadrate, rounded apically, with rectangular lower corners; length of scale about 5 mm., breadth about $5\frac{1}{2}$. The basal radii are very few, 4 to 6. A constant peculiarity is the concavity of the sides of the apical margin. The lateral circuli are parallel with the margin.

This family is evidently not allied to the Gerridæ.

MULLIDÆ. Surmulletts or goatfishes.

The characters of *Mullus*, *Upeneus*, and *Mulloidæ* have been given in the table of acanthopterygian scales above. In all these genera the lateral circuli are more or less oblique, and the basal radii are few.

SCIÆNIDÆ. Drums.

Two subfamilies can be separated as follows:
Otolithinæ (*Cynoscion*), the weakfishes. Elements of apical marginal and submarginal area with a median keel or ridge.

Sciæninæ (*Leiostomus*, *Micropogon*, *Menticirrhus*), the drums. Elements of apical marginal and sub-marginal area without any definite median keel or ridge; apical teeth pointed (*Menticirrhus*) or truncate.

The specific characters are given in the table of acanthopterygian scales above. In all the lateral circuli run parallel with the margin. The squeteague *Cynoscion regalis* is quite different from the



FIG. 30.—*Upeneus* (Mullidæ). Ctenoid area. Bureau of Fisheries.

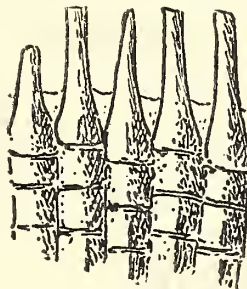


FIG. 31.—*Micropogon undulatus* (Sciænidæ). Apical teeth. Bureau of Fisheries.

others by the very numerous and densely placed basal radii, which, however, occupy only about the middle third of the scale. In all the apical elements run conspicuously in straight lines, producing a sort of fluted effect.

LATILIDÆ. Blanquellos.

In the tilefish *Lopholatilus chamaeleonticeps* Goode & Bean, from the Gulf Stream, the scales are subquadrate, the larger ones about 9 mm. long and 8 broad, the laterobasal corners rectangular. Nucleus subapical; about five basal radii coming from the nucleus, but several of these are branched, and there are a few incomplete radii, so that about 13 reach the margin; lower margin crenate; lateral circuli coarse, not dense, parallel with the margin; apical ctenoid field very well developed, the marginal teeth

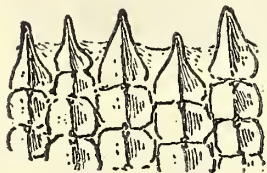
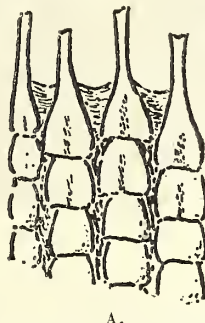
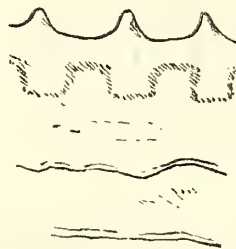


FIG. 32.—*Cynoscion regalis* (Sciænidæ). Apical teeth. Bureau of Fisheries.



A.



B.

FIG. 33.—*Lopholatilus chamaeleonticeps* (Latilidæ). Apical structures. A, normal scale; B, latinucleate scale. Bureau of Fisheries.

truncate. Latinucleate scales are greatly modified, and would not be recognized as coming from the same fish.

CIRRHITIDÆ. Cirrhitoids.

Cirrhitichthys maculatus Günther from the Red Sea (M. C. Z., 3686) has large broadly rounded scales, about 9 mm. long and $10\frac{1}{2}$ broad, with the lower margin crenate, but otherwise straight, and the laterobasal corners rectangular. The strong basal radii are about 12 to 14. The excessively fine lateral

circuli are strictly parallel with the margin, and the apical field has coarse, widely spaced longitudinal circuli. The apical margin carries a broad band of dusky skin, and is not distinctly dentate. This is certainly a peculiar scale, but my specimens are more or less latinucleate.

Suborder KURTOIDEA.

KURTIDÆ.

The scales, according to Boulenger, are minute and rudimentary.

Suborder LABYRINTHICI.

ANABANTIDÆ. Climbing perches.

I have scales of *Anabas scandens*, from Lake Buhi, Philippine Islands, and *A. munii* from Sharb-el-Aish, Egypt; the latter from the British Museum. The characters of the Climbing perch, *A. scandens*,



FIG. 34.—*Anabas*. The lines running downward are circuli.

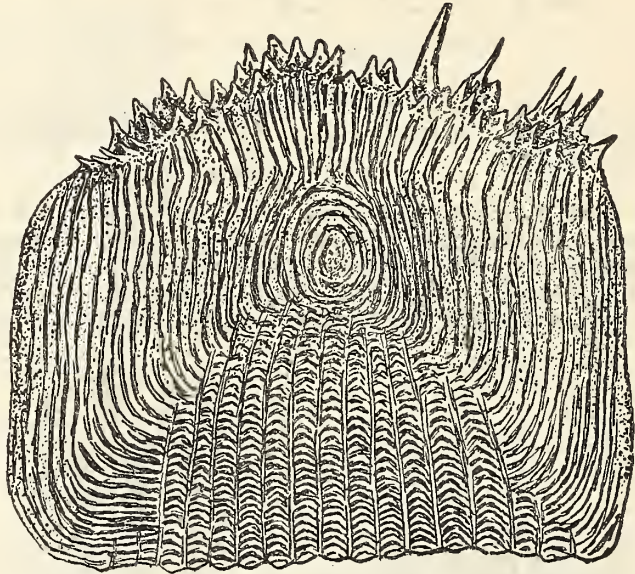


FIG. 35.—*Anabas munii* (Anabantidæ). Egypt. British Museum.

are given in the table of acanthopterygian scales above; *A. munii* scarcely differs. It is characteristic of *Anabas* that the basal circuli are dense, the lateral ones rather widely spaced, and those at the sides of the apical field strong and very far apart. The ctenoid patch is decidedly different from that of the percoids, and apparently less specialized. In *A. munii* the apical spines are broadened at base, and are singularly like those of *Aphoristia pigra*. Boulenger says the Anabantidæ are closely related to the Ophiocephalidæ, in which the scales are cycloid. Goodrich places them in a "subtribe" with the Osphromenidæ. The Anabantidæ apparently can not be derived from the percoids; they represent an early branch from the acanthopterygian stem.

Suborder HOLCONOTI. Surf-fishes.

EMBIOTOCIDÆ. Surf-fishes. (Pl. xxxviii, fig. 37, 38.)

The material studied was all collected by the Albatross, as follows: *Zalemnius rosaceus* (Jordan & Gilbert), above Santa Barbara Channel; *Amphisticus argenteus* Agassiz, St. Nicholas Island; *Phanerodon furcatus* (Girard), San Diego, Cal.; *Damalichthys argyrosomus* (Girard), Seattle, Wash. The scales are

similar, all purely cycloid, with the acanthopterygian type of basal radii. They probably represent a cycloid derivative from the ctenoid series, but they certainly can not be derived from the gerrid type I have examined. The nucleus is central or slightly above, and the basal radii are spread out fan-wise. The basal radii are about 15-19 in *Phanerodon*, 11-13 in *Damalichthys*, 9-10 in *Zalembeius*, 7-10 in *Amphisticus*. The lateral circuli are angulate in *Amphisticus* and obtusely bent in *Zalembeius*; in the large (8 mm. diam.) scales of *Phanerodon* the bending of the lateral circuli is evident near the middle, but becomes evanescent toward the periphery. The apical and basal circuli in *Phanerodon* are very fine and dense.

On comparing these scales with those of the Pœciliidæ, which appear to be primitively cycloid, it is not at first evident that there is any characteristic difference. The Pœciliids do not show the bending or angulation of the lateral circuli, and their system of basal radii is less regular and fan-like. The general facies is distinctly different, yet it is difficult to point out good diagnostic characters capable of being expressed in words. The atherinid scale, as one would expect, ranks rather with the pœciliid than the embiotocid.

Labrid and scarid scales, although cycloid, are entirely different from all these. Jordan places the Embiotocidæ in a separate suborder, Holconoti, remarking that "it contains fishes percoid in appearance, with much in common with the Gerridæ and Sparidæ, but with certain striking characteristics not possessed by any perch or bass. * * * The lower pharyngeals are solidly united, as in the Labridæ, a group which these fishes resemble in scarcely any other respects."

It seems just possible that the Embiotocidæ, although not close to the Labridæ, may agree with them in having had (as I certainly must suppose of Labridæ) no ctenoid ancestors. In this case they would apparently be distant relatives of the scombroid and atherinoid series. We have, however, in the Cichlidæ a scale development similar to that of the Embiotocidæ, and certainly from ctenoid ancestors. (Compare the scale of *Tilapia*, figured in Smithsonian Miscellaneous Collections, volume 56, no. 1.)

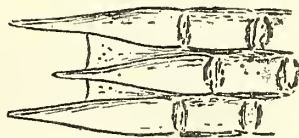


FIG. 36.—*Eupomacentrus leucostictus* (Pomacentridæ). Ctenoid structures. Bureau of Fisheries.

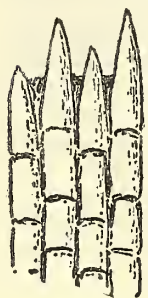


FIG. 37.—*Abudedefduf saxatilis* (Pomacentridæ). Ctenoid structures. Bureau of Fisheries.

Suborder CHROMIDES

Here we return to the normal percoid type of scale.

POMACENTRIDÆ. Coral-fishes.

I have examined the cockeye pilot, *Eupomacentrus leucostictus* (Muller & Trochel), from Key West, Fla. (W. C. Kendall), and *Abudedefduf saxatilis* (Linnæus), from Socorro Island (Albatross). The scales look like those of the Sparidæ. They are broader than long, those of *Eupomacentrus* being extremely broad (long. 3, lat. nearly 5 mm.). The basal radii are about 9 to 11. In both genera the lateral circuli are slightly oblique. This is a case in which the fishes have developed very marked structural characters, without any material evolution in the scales.

CICHLIDÆ. Cichlids. (Pl. XXXIX, fig. 39, 40, 41.)

The cichlid scales much resemble those of the pomacentrids, but the lateral circuli are not oblique, and the submarginal apical elements, instead of being truncate, are obtusely pointed and spinelike, herein approaching the condition of the Anabantidæ. It thus becomes possible to get an idea of the evolution of the complicated and specialized ctenoid patch of the percoids, the stages being represented more or less accurately by the Macruridæ, Anabantidæ, Cichlidæ, and Pomacentridæ, although, of course, this arrangement does not correctly represent the evolution of these particular families. It is also worthy of note that *Tilapia nilotica* (figured in Smith. Misc. Coll., 56, pl. 1, fig. 3) has exactly the anabantid type of circuli, with widely spaced coarse ones at the sides of the apical area. The middle of the apical area in *T. nilotica* is covered

with coarse granules or tubercles, and the scale appears to be strictly cycloid, but with a microscope it is possible to see minute short teeth all along the apical margin.

I give a key for the separation of the cichlid scales now before me:

- Apical margin apparently cycloid, the rudimentary teeth microscopical. *Tilapia nilotica*
 Apical margin evidently ctenoid, the ctenoid patch highly developed, the elements imbricated. . . 1
 1. Scales not greatly broader than long; elements of ctenoid area very distinct, relatively large, the submarginal ones broadened basally; basal radii 8 to 10 (Lake Hyanuary, Brazil, M. C. Z., 5285; *Cichla monoculus* Agassiz, det. Steindachner).
 Chaetobranchopsis ocellaris Bloch & Schneider
 Scales much broader than long; elements of ctenoid area smaller. 2
 2. Nucleus much less than a third of total length from apex; scales large, about 8 mm. long and 10½ broad; basal radii about 11; basal margin very deeply crenate (Coary, Brazil, M. C. Z., 15516). *Geophagus jurupari* Heckel
 Nucleus a third of total length from apex. 3
 3. Basal radii about 11 or 12 (Rio Novo, Brazil, M. C. Z., 15739).
 Geophagus brasiliensis Quoy & Gaimard
 Chaetobranchius flavescens Heckel
 Basal radii about 16 (Lake Hyanuary, Brazil, M. C. Z., 15706).

On the label of the *G. brasiliensis* is a manuscript generic name proposed by Steindachner for this fish, but not published. As the fish was named by Steindachner, it is perhaps really *G. steindachneri* Eigenmann & Hildebrandt, which Steindachner confused with *brasiliensis*.

The present distribution of the Cichlidae is much like that of the Characinidae, except that they occur in India and Madagascar, where the characinids are absent. Their northern origin is strongly suggested by the occurrence of a genus (*Priscacara*) in the Eocene of Wyoming. This genus has ctenoid scales of the normal cichlid type, and numerous basal radii, closely placed in the central part of the scale. The character of the ctenoid area confirms the view that the genus is cichlid, not pomacentrid.

Suborder PHARYNGOGNATHI. Labroid fishes.

The Pharyngognathi are variously limited by different authors. Thus Günther (1880) includes the Pomacentridae, Labridae, Embiotocidae, and Chromides. Goodrich (1909) has the same series: Pomacentridae, Cichlidae, Embiotocidae, Labridae, and Scaridae. Jordan (1905) includes Labridae, Odacidae, Siphonognathidae, Scaridae (Scarichthyidae). Jordan's arrangement is strongly supported by scale characters (I do not know the siphonognathid scale, however); the Günther-Goodrich series includes forms with extremely diverse scales, and is surely unnatural. The scales of the true Pharyngognathi (sens. Jordan) are characterized by the very thin apical margin, wholly without teeth, and especially the presence of apical as well as basal radii. They are thus quite unlike any other acanthopterygian scales known to me, unless they may be associated with the Atherinidae, in which the shape and general appearance of the scale is quite different. Such atherinids as *Chirostoma crystallinum* Jordan & Snyder (Lake Chapala, Mexico; J. N. Rose) and *Menidia notata* Mitchell show weak but evident apical radii, in the *Chirostoma* leading to a strong lobulation of the apical margin. Outside of the acanthopterygian series the pharyngognath scale is strikingly similar to that of the cyprinoids.

LABRIDAE. Wrasses.

Scales more or less elongate, parallel-sided, having the form seen in the cyprinid genus *Labeo* (see Biological Bulletin, vol. xx, pl. 1, fig. 8). The lateral line canals of *Labrichthys* are branched anteriorly, as shown by Günther. The regular basal radii in *Pimelometopon*, *Emmeekia*, and *Coris* are in the manner of the acanthopterygians. The species examined are *Coris venusta* Sauvage, Honolulu, H. I. (Jordan & Evermann); *Emmeekia venusta* (Jenkins & Evermann), Gulf of California (Albatross); slippery dick, *Iridio bivittatus* Bloch, Key West, Fla.; fathead, *Pimelometopon pulcher* (Ayres), Santa Barbara Island (Albatross); tautog, *Tautoga onitis* (Linnæus), Woods Hole, Mass.; and cunner, *Tautoglabrus adspersus* (Walbaum).

These may be separated by the following key:

- Inner apical circuli usually strengthened, forming wavy longitudinal ridges; apical circuli longitudinal; apical margin broadly thin, with only shadowy indications of radii; basal radii about 8, and laterobasal (ending above the basal corners) one to four on each side; scales about $3\frac{2}{3}$ mm. long and 2 broad *Pimelometopon pulcher* (subfamily Harpinæ)
- Inner apical circuli not thus modified..... 1
1. Scale is very large and broad, yellowish; about 13-14 mm. long and 11-12 broad; basal radii numerous, usually over 20..... 2
- Smaller, 7 mm. or less broad..... 3
2. Apical radii very well developed, extending from nuclear region to apex.
Iridio bivattatus^a (subfamily Julidinae)
- Apical radii very poorly developed, skin of apical region very thick.
Tautogolabrus adspersus^a (subfamily Labrinae)
3. Basal radii more than 20, laterobasal (ending above basal corners) 7 to 10; apical radii numerous and close together, though imperfect; lateral circuli very dense; scale very long, about 7 mm. long and $3\frac{1}{2}$ wide..... *Coris venusta* (subfamily Julidinae)
- Basal radii less than 20 (perhaps sometimes over 20, counting rudiments), laterobasal 1 to 7; scale not twice as long as wide^b..... 4
4. Apical radii distinct; scale about 9 mm. long and 6 broad.
Emmeekia venusta (subfamily Julidinae)
- Apical radii indistinct or imperfect; scale about 10 mm. long and 6 broad.
Tautoga onitis (subfamily Labrinae)

ODACIDÆ.

The scale of *Odax lineatus*, as figured by Günther, is entirely of the labrid type, and is very like that of *Coris*.

SCARIDÆ. Parrot-fishes. (Pl. XXXIX, fig. 44.)

Scarus croicensis (Bloch) has scales differing from those of the Labridæ in being short and broad, shield-shaped, about 6 mm. long and a little less in width. Lateral and basal circuli excessively fine; basal margin broadly truncate, lobed in middle, but not in the least crenulate; basal and apical radii very well marked, but only the inner ones reaching the nucleus; there are about 16 apical and the same number basal and laterobasal; apical region papillose, but the apical margin very broadly thin and subhyaline. A very cyprinid-looking scale.

Suborder SQUAMIPINNES. Scaly-fins.

EPHIPPIDÆ. Spadefishes.

Günther has figured the scale of *Ephippus* or *Scatophagus multifasciatus*. It is represented as strongly ctenoid, with several rows of teeth; the basal radii are feebly indicated by a few broad depressions.

CHÆTODONTIDÆ. Butterfly-fishes.

I have *Chætodon ulietensis* Cuvier & Valenciennes from Apia, Samoa; *C. bricei* Smith, from Katama Bay; and *Pomacanthus arcuatus* (Linnæus). The characteristic ctenoid sculpture of these genera is shown in figures 38 and 39. The marginal teeth in *Chætodon* are very sharp, and both the teeth and the truncate submarginal elements have a specialized triangular area, shaped like a thorn, superimposed, as it were, upon their surface. All this is exactly the same in the Atlantic *C. bricei* as in the Pacific *C. ulietensis*, notwithstanding the great geographical separation.

In *C. ulietensis* the ctenoid area is very large and well-formed in all its details; the basal radii are about 17; laterobasal angles obtuse; lateral circuli very slightly oblique. (Pl. XXXIX, fig. 45.)

In the *Pomacanthus* the ctenoid region is much modified, the broad though sharp apical teeth each having a very strong rib which extends more than a millimeter basad, the successive ctenoid elements

^a Superficially these scales look exactly alike.

^b In young *Tautoga* scales, 5 mm. long, the length is twice the width.

having perhaps coalesced. The basal radii are weak, about 3 to 7, and the excessively dense lateral circuli are not at all oblique.

The fishes represent two subfamilies, Chætodontinæ and Pomacanthinæ.

Suborder SCLERODERMI. Hardskin fishes.

BALISTIDÆ. Trigger-fishes.

The leather jacket, *Balistes carolinensis* Gmelin, has peculiar thickened, extremely broad scales, about $3\frac{1}{4}$ mm. long and 7 broad, the apical half covered with large tubercles, which appear to be homologous with the spines of the Macruridæ. These tubercles or spines are curiously suggestive of those on

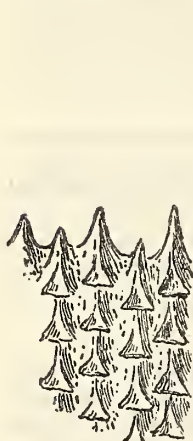


FIG. 38.—*Chatodon ulienensis* (Chætodontidæ). Ctenoid structures. Bureau of Fisheries.



FIG. 39.—*Pomacanthus arcuatus* (Chætodontidæ). Ctenoid structures. Bureau of Fisheries.

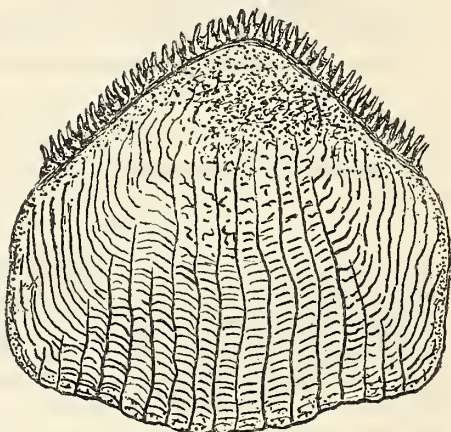


FIG. 40.—*Ctenogobius* (or *Rhinogobius*) *hadropterus*. Japan. Stanford University.

the scutes of *Acipenser*. Those along the basad margin of the tuberculate area are arranged in a regular row, which is angled in the middle, the very broad angle looking apicad. A quite different looking *Balistes* scale, with six large spines, is figured in the Cambridge Natural History, Fishes, page 191.

MONACANTHIDÆ. Filefishes.

A scale of *Monacanthus*, of the same general type as that of *Balistes*, is figured in the Cambridge Natural History, on the page just cited. The large spines are arranged much as in the macrurids (e. g., *Macrurus carminifer* Garman).

I have material of the orange filefish, *Ceratacanthus schæpfii* (Walbaum), from near Woods Hole, Mass., kindly given to me by Dr. E. Linton. The skin contains many minute spots of black pigment, and in places a fine dark blue pigment, which does not turn red in acids. The scales are shaped nearly as in *Monacanthus* and the exposed area of each has numerous large spine-like structures, one of which is much larger than the others. The concealed part of the scale is striate, with the appearance under the microscope of tree trunks closely packed, branching more or less distally.

Suborder GOBIOIDEA.

GOBIIDÆ. Gobies.

Jordan remarks that the Gobiidæ have no near relations among the spiny-rayed fishes. Günther has figured the scale of *Gobius*, and I am indebted to Dr. Jordan for material of the Japanese *Mapo fuscus* (from Tanegashima), *Ctenogobius virgatus* (from Shiogama) and *C. hadropterus* (from Tanegashima). These fishes have basal radii as in the acanthopterygians, but the nucleus is at the very apex of the scale, and the marginal teeth form a single apical row as in the Aphredoderidæ; exactly, also, as in the ctenoid African Characinidæ. In the ctenoid African characinids the basal radii are not developed, or rather are represented by mere folds; in *Aphredoderus* they are very distinct, but not numerous; in the Gobiidæ they are very numerous and close together. In the gobiids the relatively short (though very strongly developed) apical teeth are more like those of the ctenoid characinids than those of *Aphredoderus*, and the characinid *Distichodus*, with its more or less pointed or angled apical margin, suggests the very strong angulation of that margin seen in the Gobiidæ. *Percopsis* has the apical nucleus and angled marginal of the gobiids, but the marginal teeth are less developed, and the basal radii are absent.



FIG. 41.—*Leptecheneis naucrates* (Echeneidæ). Apical end to the right. Bureau of Fisheries.

The gobiid scales before me may be separated as follows:

Lateral margin (from apicolateral to basolateral angles) somewhat larger than apical margin of one side; some radii lateral (entering margin above basolateral corner); radii about 22. *Mapo fuscus*
Lateral margin shorter or not longer than apical margin of one side; no radii lateral 1
1. Lateral circuli quite dense; radii about 30, some imperfect.

Ctenogobius virgatus Jordan & Snyder

Lateral circuli not dense; radii about 14, some imperfect.

Ctenogobius hadropterus Jordan & Snyder

Latinucleate scales are common and are of course much modified, though they retain the characteristic margin.

Suborder DISCOCEPHALI.

ECHENEIDÆ. Remoras.

I had examined the shark sucker, *Leptecheneis naucrates* (Linnæus), collected at Woods Hole, Mass., and concluded that there were no scales. Dr. E. Linton, who was working on the parasites of this fish, suggested that scales might be found in the skin, and so it proved. The completely embedded scales have an elongate-lanceolate form, pointed or obtuse at the ends, length about $2\frac{1}{2}$ mm. The sculpture consists only of rather widely spaced concentric circuli. No other similar scale is known to me, though in the matter of sculpture (though not at all in form) the scales substantially agree with those of *Lota*.

Suborder SCLEROPAREI.

SCORPÆNIDÆ. Scorpion fishes.

In this family the scales may be fully ctenoid, or may entirely lose the teeth.

Subfamily SEBASTINÆ.

Sebastes Cuvier, rosefish. *S. marinus* (Linnæus) from Woods Hole (V. N. Edwards), has small oblong scales with five basal radii, very widely spaced circuli, and three or four very large and stout apical spines (fig. 74). The apical circuli are angled in the middle.

Sebastes Gill. Mr. A. R. Moore very kindly sent a number of species of *Sebastes* from California, showing that the genus has rather large scales, very strongly ctenoid, with very numerous, strong and crowded apical teeth, and the ctenoid patch with several rows of distinct elements (fig. 76). The basal radii are fairly numerous.

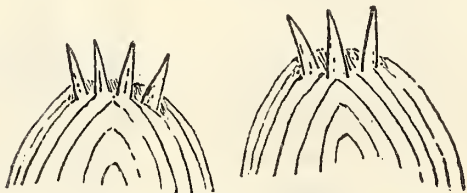


FIG. 42.—*Sebastes marinus* (Scorpænidæ). Apical structures. Bureau of Fisheries.



FIG. 43.—*Sebastes paucispinis* (Scorpænidæ). California.

Mr. Moore sent *S. paucispinis* (Ayres), *S. flavidus* (Ayres), *S. mystinus* Jordan & Gilbert, *S. ruberrimus* Cramer, *S. constellatus* (Jordan & Gilbert), *S. rosaceus* (Girard), *S. carnatus* (Jordan & Gilbert), and *S. nebulosus* (Ayres), and although the scales of all these were carefully examined by Miss Evelyn Moore and myself, we could find no satisfactory specific characters.

Subfamily SCORPÆNINÆ.

Scorpena Linnæus. *S. plumieri* Bloch, from Katama Bay, has small scales a little over 1 mm. long, and about 1 mm. broad, with coarse but dense circuli, and about seven basal radii. The circuli fail in the apical field, and the margin is cycloid, with, however, occasional rudiments of minute teeth.

Helicolenus Goode & Bean. *H. dactylopterus* (De la Roche), from off Woods Hole, in gulf weed, has comparatively large scales, oval in form, about 4 mm. long and 3 wide. They are cycloid, and formed much as in *Scorpena*, but with about 13 basal radii. The apical field is covered with little tubercles, resulting from the breaking up of the apical circuli. The basal circuli are very minutely beaded. Jordan & Evermann state that this genus has ctenoid scales on the top and sides of the head, which is not true of *Scorpena*.

So far as the scales go *Sebastes* should be in the most primitive of the above genera.

COTTIDÆ. Sculpins.

In the fossil *Lepidocottus brevis* (Agassiz), from the Upper Miocene at Wangen, Baden (E. Penard), the scales are as in the Gobiidæ, with angled apical margin, a single row of marginal teeth, apical nucleus,

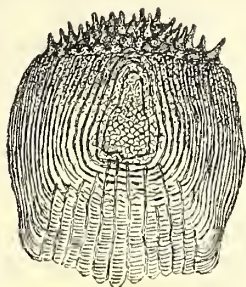


FIG. 44.—*Sebastodes paucispinis* (Scorpenidæ). California.

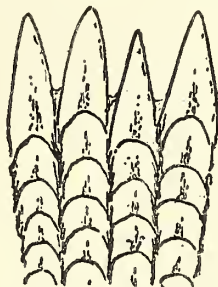


FIG. 45.—*Prionotus strigatus* (Triglidae). Apical structures. Bureau of Fisheries.

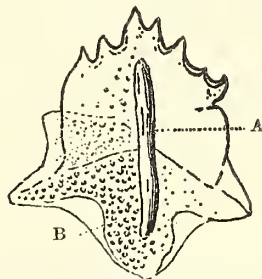


FIG. 46.—*Cephalacanthus volitans* (Cephalacanthidae). A, high crest; B, pigment spots. Bureau of Fisheries.

etc. Is it quite certain that this fish really is a cottid? Species of *Lepidocottus* have actually been described under *Gobius*.

PLATYCEPHALIDÆ. Flatheads.

Günther has figured the scale of *Platycephalus cirrhonotus*. It is of typically ctenoid character with about four basal radii, but long and parallel sides, the shape suggesting the labrids.

Suborder CRANIOMI.

TRIGLIDÆ. Sea robins.

Prionotus strigatus (Cuvier & Valenciennes), the striped sea robin, from Woods Hole, has the scales subquadrate, about $4\frac{1}{2}$ mm. long and 5 broad, typically ctenoid, with the ctenoid patch large; basal radii about seven or eight; lateral circuli parallel with margin. The submarginal apical elements are very short, broader than long.

CEPHALACANTHIDÆ. Flying gurnards.

Cephalacanthus volitans (Linnaeus), the flying gurnard, from Woods Hole, has greatly modified, strongly keeled scales, with the margin toothed. The form is sufficiently shown in the accompanying figure. There is nothing in the scales to suggest affinity between the triglids and cephalacanthids.

Suborder HETEROSOMATA. Flatfishes.

I have given an account of the scales of these fishes in Proceedings of the Biological Society of Washington, volume XXIV, pages 209-211; it remains now only to present some figures, and a few additional details.

PLEURONECTIDÆ. Flounders.

I am indebted to Dr. F. B. Sumner for scales of *Platophrys* (or *Rhomboidichthys*) *podas*, from the Bay of Naples. In my table, in the paper just cited, they run to *Platophrys constellatus*, from which they scarcely differ. Both have traces of radial lines crossing the lateral circuli, producing a sort of delicate cancellation. The apical teeth in *P. podas* are about 7 or 8, very stout and strong.

SOLEIDÆ. Soles.

Scales of a species of *Cynoglossus* from Hongkong (M. C. Z., 11329) are large, about 9 mm. long and nearly 6 broad; strongly ctenoid on the upper (pigmented) side of the fish, strictly cycloid below.

The basal radii are excessively numerous and close together (pl. XL, fig. 52). The ctenoid elements are formed essentially as in the tongue sole, *Aphoristia pigra*, which belongs to the subfamily Cynoglossinæ. A truly remarkable feature, equally developed in the cycloid and ctenoid scales, is found in the basal (interradial) circuli, which as they leave the radii are directed obliquely apicad, and in the middle third of the interradial field are broken up into minute more or less pyriform bodies. In *Symphurus* (or *Aphoristia*) *piger* the beginning of this is seen in the fact that some of the interradial sections of the circuli are bent and V-like. The extreme and unique modification of the basal circuli in *Cynoglossus* is important, as I think it amounts to a demonstration that *Cynoglossus* (with cycloid scales on the lower side) is not a primitive member of the Soleidæ and is not connected in any way with the pleuronectids. The general characters of the fish also support this idea.

Suborder JUGULARES.^a

BLENNIIDÆ. Blennies.

The rock eel, *Pholis gunnellus* (Linnæus), from Menemsha Bight, Mass., has extremely minute more or less oval cycloid scales, with the nucleus a little above the middle, very widely spaced circuli,

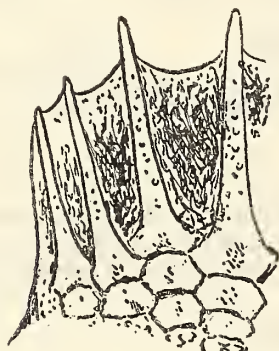


FIG. 47.—*Achirus lineatus* (Soleidæ).
Apical structures. Bureau of
Fisheries.



FIG. 48.—*Aphoristia pigra*
(Soleidæ). Apical
structures. Bureau of
Fisheries.



FIG. 49.—*Solea solea*
(Soleidæ). Apical struc-
tures. Bureau
of Fisheries.

and rather widely separated radii basally and laterally. *Ulvaria subbifurcata* Storer, taken by Mr. V. N. Edwards from the stomach of a red-breasted merganser (*Merganser serrator* Linnæus), has similar but longer scales, with the nucleus more apicad, and the 3 to 6 radii all basal. The circuli fail in the apical region.

These are very degenerate scales, which do not suggest any acanthopterygian affinities.

ANARHICADIDÆ. Wolf-fishes.

The wolf-fish, *Anarhichas lupus* (Linnæus), from Woods Hole, has small nearly circular scales, with central nucleus and radii almost all around, in every way very like those of *Pholis*.

GADOPSIDÆ. New Zealand "trouts."

Gadopsis, a fresh-water genus of New Zealand and Australia, has been figured by Günther. The scale is long oval, cycloid, with regular circuli, which are not dense; nucleus a little apicad of middle; six strong radii. All this is very close to the blenniid *Ulvaria*. The fact that the three families of

^a See also Proceedings Biological Society of Washington, vol. xxvi, p. 89-92.

Jugulares, of which the scales are known to me, agree so closely in scale characters must indicate that, degenerate as they are, these scales really represent an ancient type, less modified than other characters of the fishes on which they occur.

Suborder ANACANTHINI. Gadoid fishes.

I have discussed this series at some length in Proceedings of the Biological Society of Washington, volume XXIV, pages 211-212. I now offer some figures.

GADIDÆ. Cods.

Since the account cited above was printed I have examined scales of the European burbot, *Lota lota* (Linnæus), from the Danube (M. C. Z. 12366), and the American burbot, *L. maculosa* (Le Sueur), from

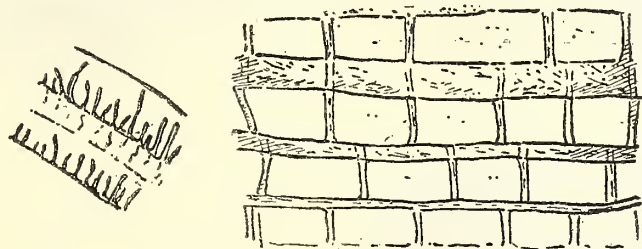


FIG. 50.—*Brosmius brosme* (Gadidæ). Sculptural details, submarginal region. Bureau of Fisheries. Smaller figure shows sculpture of a latinnucleate scale near middle.

Erie, Pa. (Bureau of Fisheries). This genus, typical of the subfamily Lotinæ, has extremely minute circular to suboval scales, with nucleus central or almost; coarse, widely separated circuli, and no radii. It is, however, to be noted that the circuli are crenate or denticulate on the inner margin, a relic of the

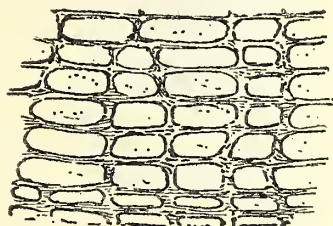


FIG. 51.—*Melanogrammus æglepinus* (Gadidæ). Details of sculpture, submarginal region. Bureau of Fisheries.

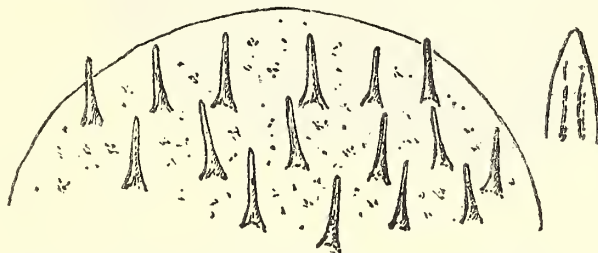


FIG. 52.—*Cælorhynchus caribbaeus*, and spine of *Macrurus bairdii* (Macruridæ). U. S. National Museum.

condition so well marked in *Brosmius*. I am quite unable to find any difference between the scales of the European and American species.

A scale of *Urophycis regius* is figured on plate XL (fig. 51.)

MACRURIDÆ. Grenadiers. (Pl. XL, fig. 48.)

Dr. S. Garman (Mem. Mus. Comp. Zool., vol. XXIV) has figured the scales of a number of species of *Macrurus*, namely *M. barbiger* Garman, *M. bulbiceps* Garman, *M. bucephalus* Garman, *M. liraticeps*

Garman, *M. fragilis* Garman, *M. tenuicauda* Garman, and *M. carminifer* Garman. *M. barbiger* has no teeth whatever; *M. fragilis* is represented with a single little tooth. *M. bulbiceps* has very many little spines in the apical field; *M. carminifer* has very large spines. The figure of *M. tenuicauda* looks like a latinucleate scale.

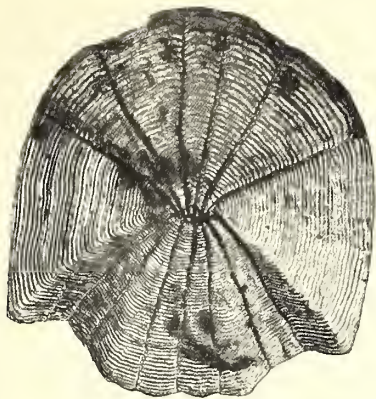
Order PEDICULATI.

ANTENNARIIDÆ. Fishing-frogs.

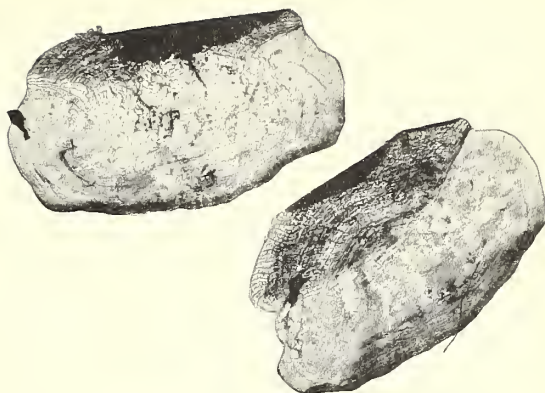
Dr. Garman, in the work just cited, figures the spiniferous scales of *Chaunax coloratus* Garman. In the Cambridge Natural History, Fishes, page 191, is a figure of the scale of *Antennarius hispidus*.

OGCOCEPHALIDÆ. Batfishes.

In the Cambridge Natural History, on the page just cited, is a figure of the spine-bearing scale of *Ogcocephalus* or *Malthe vespertilo* (Linnæus).



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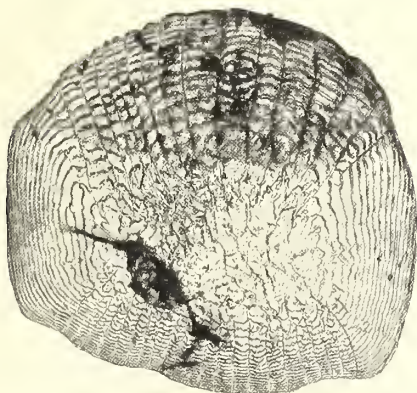
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FIG. 1.—*Placopharynx duquesnii*. Cherokee, Iowa (S. F. Meek).
 FIG. 2.—*Acanthorhodus tennensis*. Shanghai (Swinhoe). The wavy apical radii are not well shown.
 FIG. 3.—*Algansea sallaei*. Guanajuato, Mexico (A. Dugès).
 FIG. 4.—*Chela paralaubuca*. British Museum.
 FIG. 5.—*Chondrostoma meigii*. San Domingo de Silos, Burgos, Spain (Gonzales).
 FIG. 6.—*Nocomis kentuckiensis*. Stone River, Tennessee.

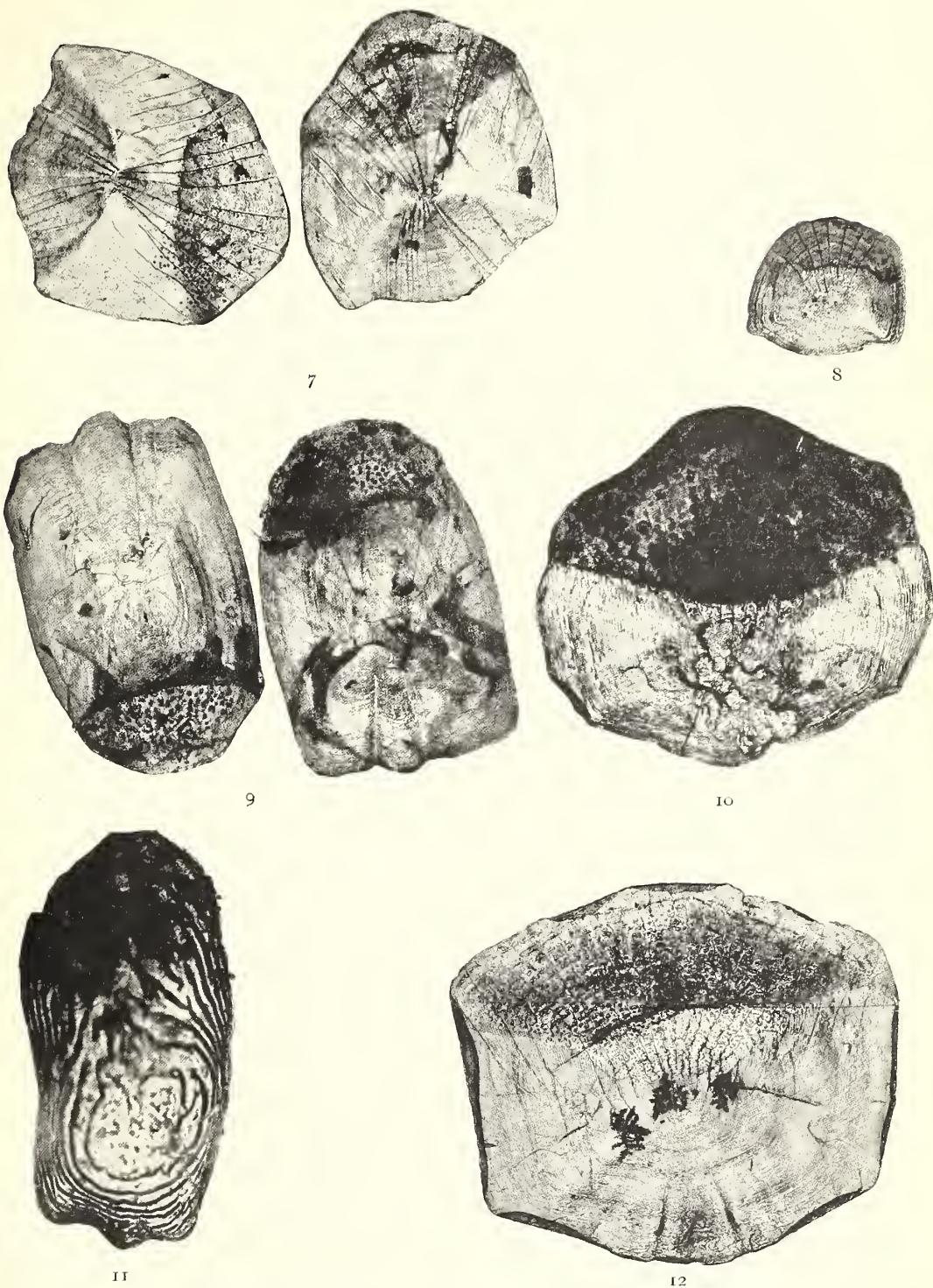
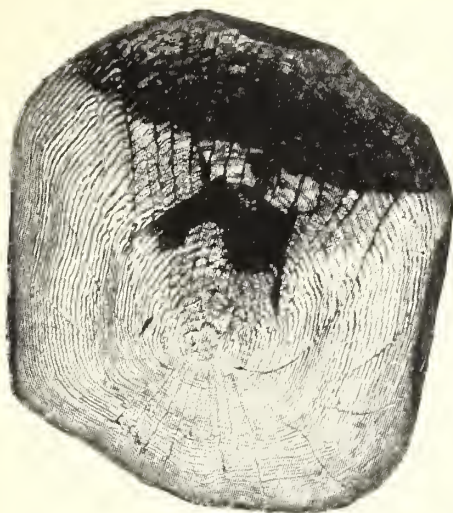
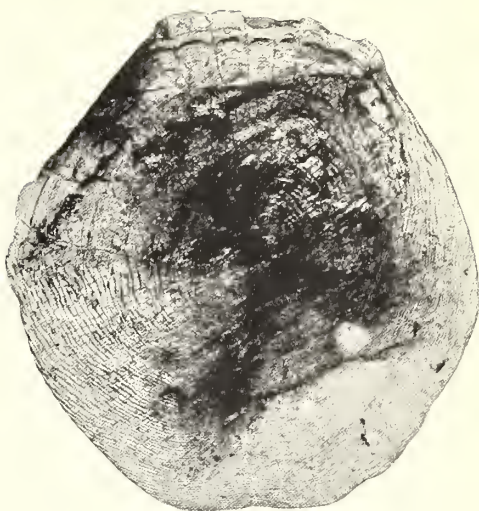


FIG. 7.—*Luciosoma trinema*. Upper Baram River (C. Hose).
 FIG. 8.—*Notemigonus chrysoleucus*. Falmouth, Mass.
 FIG. 9.—*Rohitta lineata*. Sittang River (E. W. Oates). British Museum.
 FIG. 10.—*Scaphiodon muscatensis*. Muscat, Arabia. British Museum.
 FIG. 11.—*Schizothorax intermedius*. Kashgar. British Museum.
 FIG. 12.—*Semiplotus maclellandi*. Assam (F. Day). British Museum.



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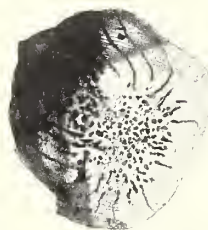
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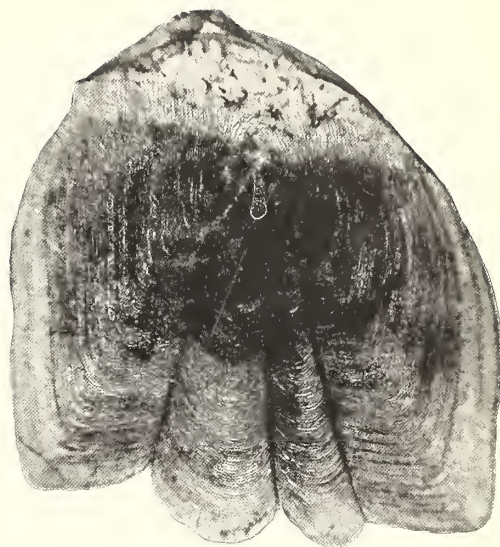


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FIG. 13.—*Capoeta fratercula*. Persia. British Museum.
 FIG. 14.—*Culter erythropterus*. R. Keroulen, Mongolia (Chaffanjon). British Museum.
 FIG. 15.—*Leptobarbus hoeveni*. Tinjar River (C. Hose). British Museum.
 FIG. 16.—*Oreinus grahami*. British Museum.
 FIG. 17.—*Homaloptera maculata*. Khassya (Dr. Jerdon). British Museum.



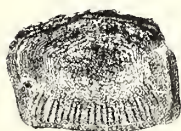
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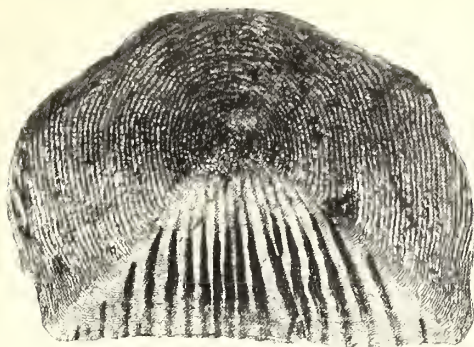


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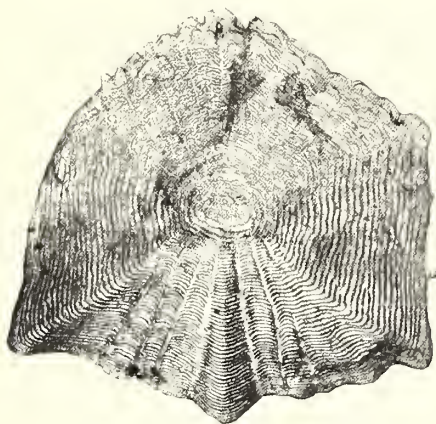
FIG. 18.—*Clupanodon pseudohispanicus*. Woods Hole, Mass.
 FIG. 19.—*Synodus foetens*. Galveston, Texas (Evermann).
 FIG. 20.—*Lucius lucius*. Toledo, Ohio (Rutter).
 FIG. 21.—*Fundulus majalis*. Latinucleate scale.
 FIG. 22.—*Fundulus heteroclitus*. Woods Hole, Mass.



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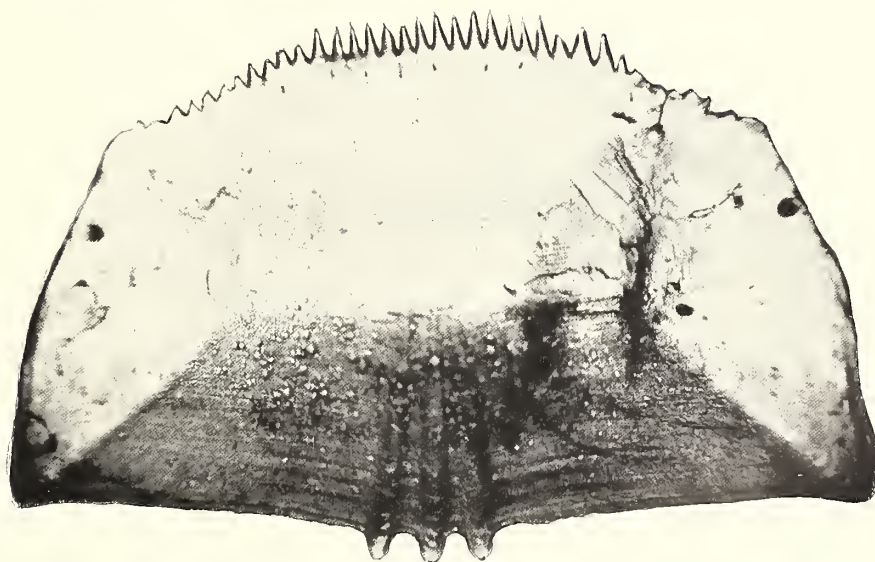
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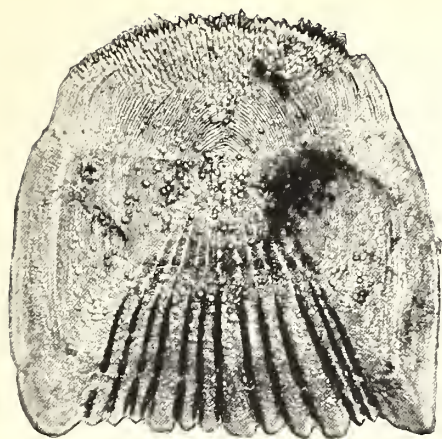


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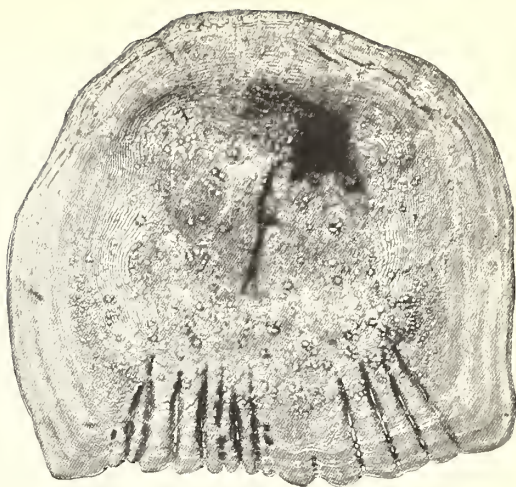


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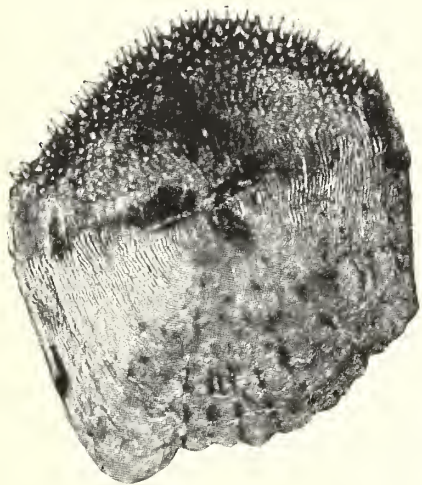
FIG. 23.—*Mollienisia latipinna*. Gordons Pass, Florida (Henshall).
 FIG. 24.—*Scombresox saurus*. Woods Hole Collection.
 FIG. 25.—*Chirostoma crystallinum*. Lake Chapala, Mexico (J. N. Rose).
 FIG. 26.—*Holocentrum laticeps*. Kauai, H. I. Museum of Comparative Zoology.
 FIG. 27.—*Caranx hippos*. Woods Hole Collection.



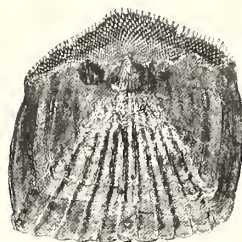
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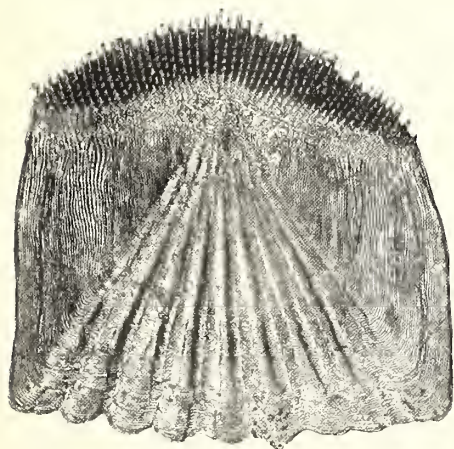
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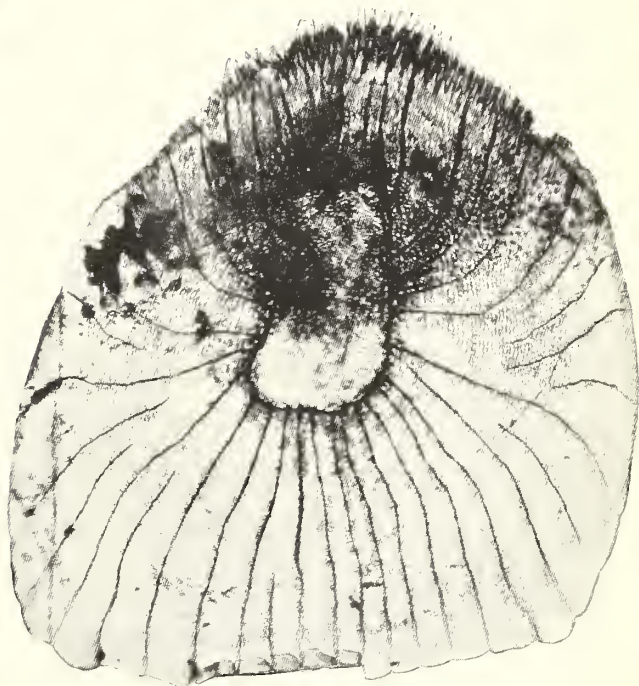
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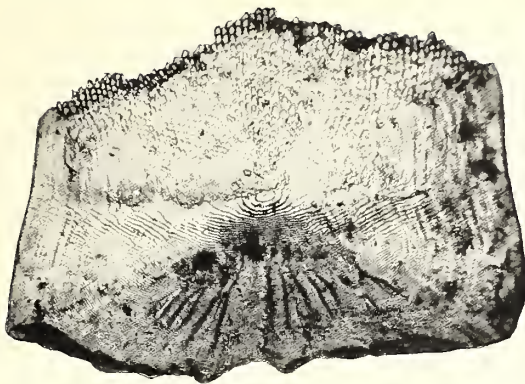


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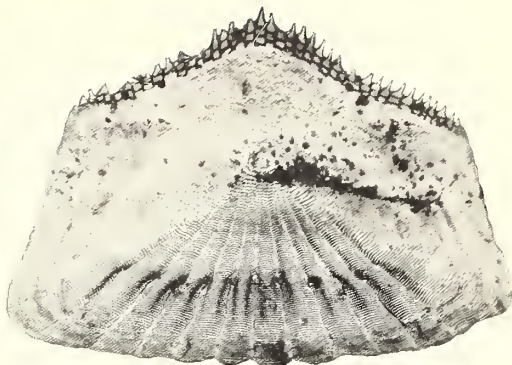


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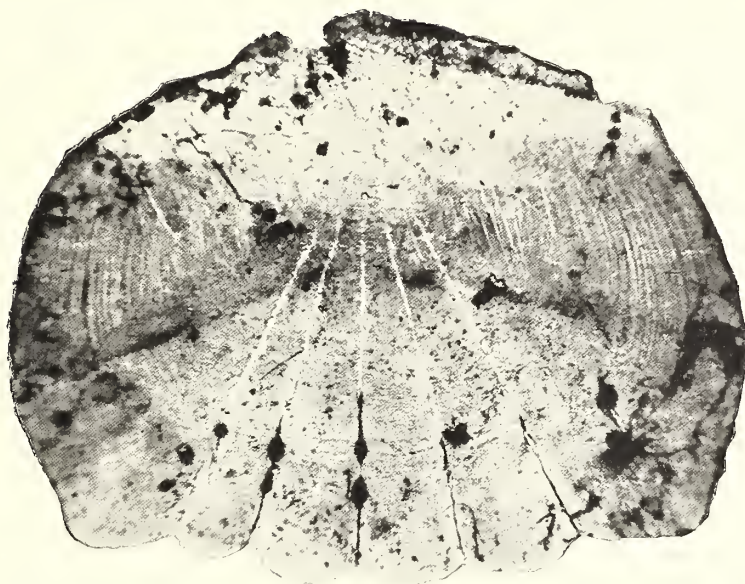
FIG. 28.—*Mesogonistius chetodon*. Trenton, N. J.
 FIG. 29.—*Ambloplites rupestris*. Huntington, Tenn.
 FIG. 30.—*Archoplites interruptus*. San Francisco, Cal.
 FIG. 31.—*Centropistes striatus*. Woods Hole, Mass.
 FIG. 32.—*Pleistops corallicola*. Ebon Islands. Museum of Comparative Zoology.
 FIG. 33.—*Orthoprists chalcus*. Guaymas or Clarion Island. (Albatross).



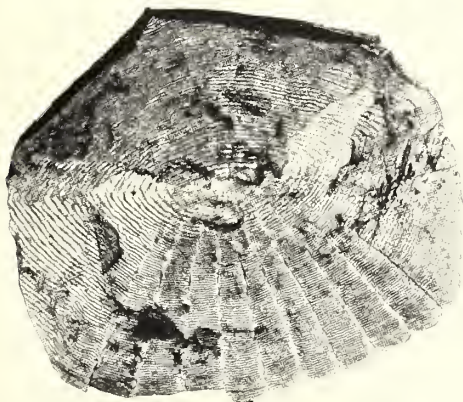
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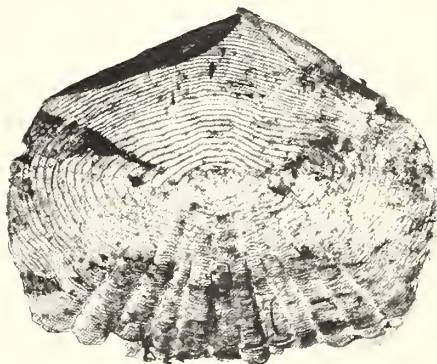
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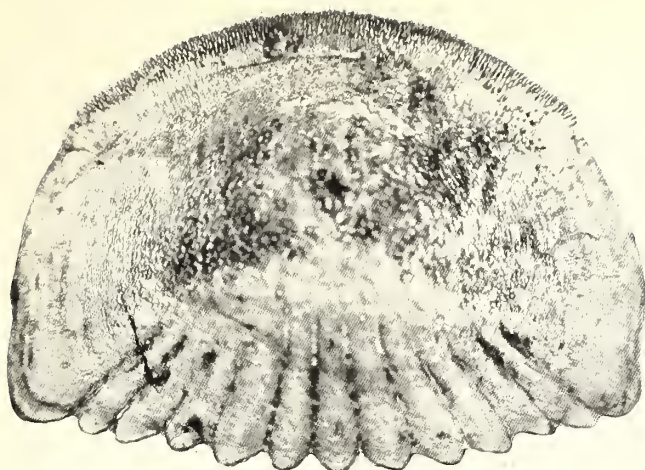


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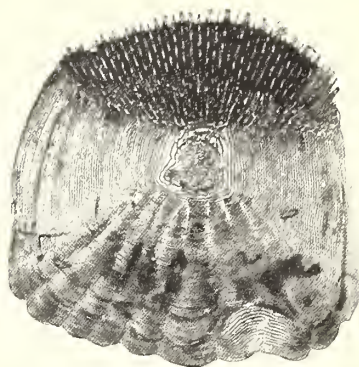


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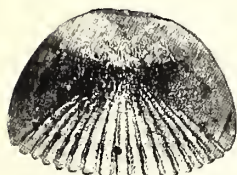
FIG. 34.—*Box vulgaris*. Vienna Museum.
 FIG. 35.—*Smaris* sp. Trieste.
 FIG. 36.—*Gerres gula*. Brazil. Museum of Comparative Zoology.
 FIG. 37.—*Amphistictus argenteus*. St. Nicholas Island. (Albatross.)
 FIG. 38.—*Zalemibus rosaceus*. Above Santa Barbara Channel. (Albatross.)



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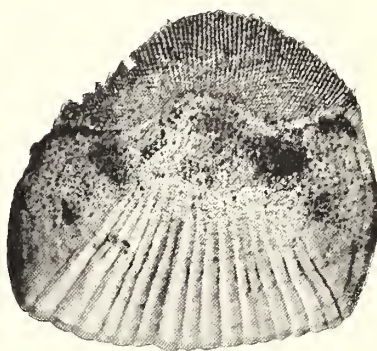
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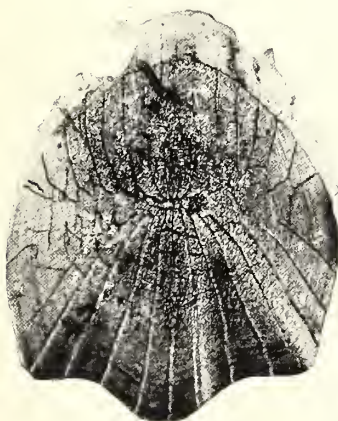
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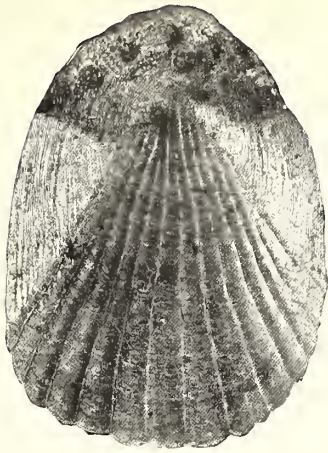


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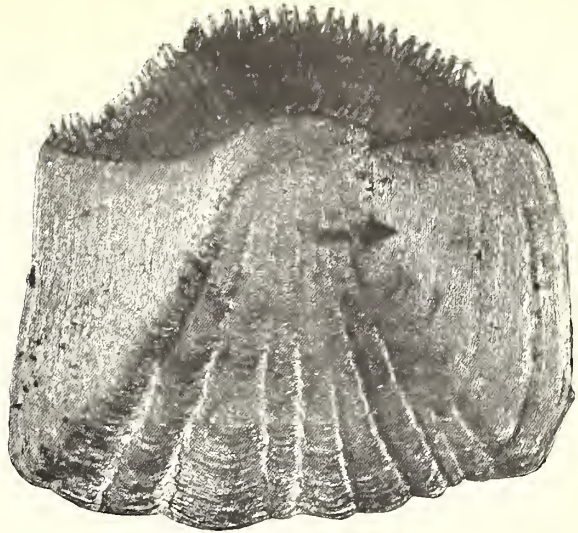


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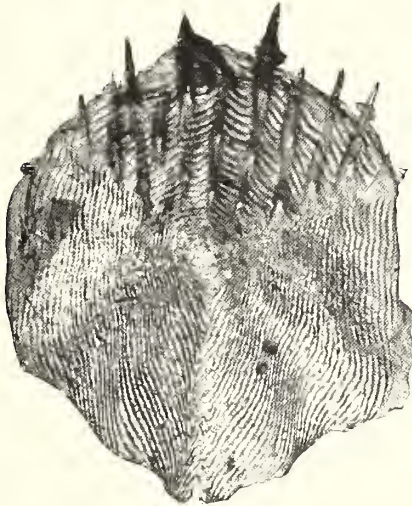
FIG. 39.—*Geophagus brasiliensis*. Rio Novo, Brazil.
 FIG. 40.—*Cichla monoculus*. Lake Hyannary, Brazil. Museum of Comparative Zoology.
 FIG. 41.—*Chatobranchius flavescens*. Lake Hyannary, Brazil.
 FIG. 42.—*Pimelometopon pulcher*. Santa Barbara Islands (Albatross.)
 FIG. 43.—*Emmikia venusta*. Gulf of California. (Albatross.)
 FIG. 44.—*Scarus croicensis*. Woods Hole Collection.
 FIG. 45.—*Chatodon ulietensis*. Apia, Samoa. (Jordan.)



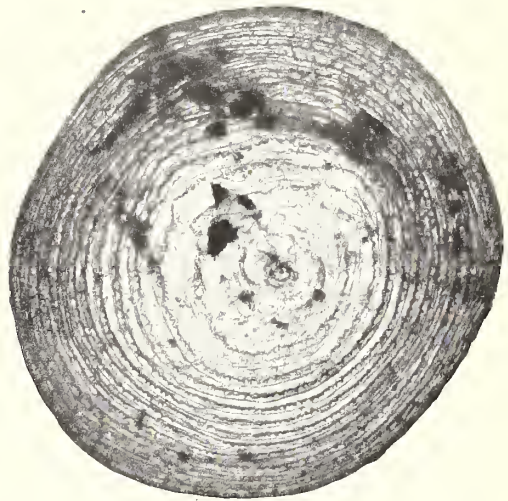
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FIG. 46.—*Helicolenus dactylopterus*. Off Woods Hole.
 FIG. 47.—*Prionotus strigatus*. Woods Hole, Mass.
 FIG. 48.—*Macrurus* sp. Albatross station 2426.
 FIG. 49.—*Lota vulgaris*. Danube. Museum of Comparative Zoology.
 FIG. 50.—*Gadus callarias*. Woods Hole Collection.
 FIG. 51.—*Urophycis regius*. Woods Hole, Mass.
 FIG. 52.—*Cynoglossus* sp., upper side. Hongkong. Museum of Comparative Zoology.

A NEW METHOD FOR THE DETERMINATION OF THE FOOD
VALUE OF PROTEINS, WITH APPLICATION TO
CYNOSCION REGALIS



By George F. White and Adrian Thomas

A NEW METHOD FOR THE DETERMINATION OF THE FOOD VALUE OF PROTEINS, WITH APPLICATION TO *CYNOSCION REGALIS*.



By GEORGE F. WHITE and ADRIAN THOMAS.



It is frequently desired to compare the rate and course of digestion of various proteins by enzymes according to methods which, while not complicated, will give distinctive and reliable results. Van Slyke's^a method for the determination of amino acids has been applied by White and Crozier^b with evidently great success to a comparison of the tryptic proteolysis of beef and several fish meats. The ease of manipulation of the apparatus, the brief time required for a determination, and the regularity of the experimental data, make the process generally useful. The conclusions drawn also conform with those from metabolism experiments, making the results of still greater value.

The method which Sørensen^c has proposed for the estimation of amino acids and polypeptides, by titration with caustic soda after the addition of formaldehyde, by its simplicity suggests itself for artificial digestion processes. It is the object of this article to show its application to the hydrolysis of *Cynoscion regalis* (squeteague, weakfish) by trypsin, and to compare the results with those obtained by Van Slyke's method.

The squeteague was boiled in water for a quarter of an hour, allowed to drain from excess of liquid, and preserved ice-cold. An analysis of two samples gave an average of 4.52 per cent nitrogen.

The digestion was carried on in 250 c. c. volumetric flasks placed in a thermostat kept at temperature of 37.5° C. Enough meat to furnish 1.5 g. of nitrogen was weighed out, ground up with water together with 1 g. of trypsin, and this mixture poured into the flask; 25 c. c. of N/10 sodium hydroxide solution was added, and the whole made up to 250 c. c. with water. Trypsin is presumably most active in a medium made alkaline with sodium carbonate, but the presence of this salt would interfere with the titration for the amino acids where phenolphthalein must be used as an indicator, so that the alkalinity was insured by the presence of the hydrate. Separate mixtures were made

^a Van Slyke, D. D.: A method for quantitative determination of aliphatic amino groups. *Journal of Biological Chemistry*, vol. IX, p. 185-204, 1911. Baltimore.

^b White, G. F. & Crozier, W.: Comparative proteolysis experiments with trypsin. *Journal of the American Chemical Society*, vol. 33, p. 2042-2048, 1911. Easton, Pa.

^c Sørensen, S. P. L.: *Fermentstudien*. *Biochemische Zeitschrift*, bd. 7, p. 45-107, 1907. Berlin.

and analyses run in duplicate for the time periods of 1, $\frac{1}{2}$, 2, 5, and 8 hours, respectively. A sample similar to the above but containing no trypsin was also prepared and analyzed with the others according to the following method: At the end of the desired time of digestion, the mixtures were filtered and aliquot portions of the filtrate taken for the various tests; 10 c. c. were used for the determination of total soluble nitrogen by the Kjeldahl method; 10 c. c. for the amino nitrogen by Van Slyke's method; 20 c. c. were treated with 10 c. c. of 40 per cent formaldehyde solution and titrated to a distinct pink color with N/10 sodium hydroxide solution. We found that in every case a distinct end point was obtained, duplicate analyses agreeing within 0.2 per cent. Finally, 10 c. c. of the filtrate from the digested fish were completely hydrolyzed by prolonged digestion on the water bath with 40 c. c. of concentrated hydrochloric acid. This solution was evaporated to dryness, made up to 50 c. c. with water, 10 c. c. tested for amino nitrogen by Van Slyke's method, and 20 c. c. analyzed for amino acids by Sørensen's method.

All the results as obtained above were corrected for amino nitrogen before and after complete hydrolysis, for total soluble nitrogen, and for amino acids as determined by titration with caustic soda, by carrying through the same experiments with trypsin and alkali, but with no protein. Correction was also made for the alkali required to neutralize the formaldehyde solution.

In table I are presented the results obtained by applying Van Slyke's method to the tryptic proteolysis of squeteaguc. The average size of the peptides was calculated by dividing the amount of amino nitrogen present after complete hydrolysis with hydrochloric acid by that in the solution before such hydrolysis. The last two columns of data show the increase with time of proportion of soluble to insoluble nitrogen and of amino to total soluble nitrogen, respectively. The average results of duplicate analyses are given.

TABLE I.—TOTAL AND AMINO NITROGEN IN SOLUTIONS OF CYNOSCION REGALIS
HYDROLYZED BY TRYPSIN.

Time in hours.	Soluble nitrogen.	Insoluble nitrogen.	Amino nitrogen.	Amino nitrogen after hy- drolysis.	Average size of peptids.	Soluble 100X total nitrogen.	Amino 100X soluble nitrogen.
0	0.170	1.330	0.017	0.056	3.29	11.32	10.00
$\frac{1}{2}$	1.115	.385	.230	.464	2.02	74.32	20.63
1	1.175	.340	.250	.464	1.86	78.34	21.27
2	1.173	.327	.289	.464	1.61	78.20	24.63
5	1.361	.139	.357	.....	.....	90.72	26.23
8	1.432	.068	.406	.646	1.59	95.45	28.35

In table II are given the average results of the analysis of the proteolyzed solutions according to Sørensen's method. In column 2 the figures represent cubic centimeters of N/10 sodium hydroxide solution required for neutralization after addition of formaldehyde solution. Column 3 is the same for the solutions after complete hydrolysis with hydrochloric acid. The next column gives the ratio of the latter to the former. In

column 5 are given figures for amino nitrogen calculated from the data in column 2, while the values in the last column were obtained by calculating the per cent calculated amino nitrogen of the total soluble nitrogen.

TABLE II.—ANALYSIS BY SÖRENSEN'S METHOD OF SOLUTIONS OF CYNOSCION REGALIS HYDROLYZED BY TRYPSIN.

Time in hours.	Quantity N/10 NaOH required.	Quantity N/10 NaOH required after hydrolysis.	Average size of peptids.	Amino nitrogen calculated.	Amino nitrogen 100X soluble nitrogen.
	<i>c. c.</i>	<i>c. c.</i>			
0	24.85	125.0	5.02	0.035	20.52
½	182.8	536.8	2.94	.257	23.02
1	213.8	598.0	2.80	.300	25.87
2	232.9	.....	.....	.327	27.87
5	293.5	776.0	2.64	.412	30.28
8	314.8	787.1	2.50	.442	30.87

From table I it is seen from the ratio of the soluble to the total nitrogen that the fish meat goes very rapidly into solution, 74.32 per cent of the nitrogen being in solution at the end of a half hour's digestion. Solution, however, is not complete in eight hours' time, a fact which is apparently not in harmony with the results of White and Crozier,^a who found with the proteins they studied that all the nitrogen was in the soluble form in four to eight hours. The trypsin used, a commercial sample, was of the same activity in both series of experiments. These latter experiments were carried on in a medium made alkaline with sodium carbonate, while the experiments described in this article required sodium hydroxide for reasons already stated. Schierbeck^b has proved that the action of trypsin in digesting proteins is accelerated by the presence of carbon dioxide in solutions which are slightly alkaline, and it is very probably at least partly due to this fact that the above differences are found. The variation of the proportion of soluble to total nitrogen with increase of time is shown graphically in figure 1. Extrapolation of the curve would indicate that the squeteague would be completely dissolved in about 14 hours.

White and Crozier have shown that their artificial digestion experiments gave results agreeing closely with those obtained by metabolism work with dogs, rates of digestion of different proteins being in the same ratio to each other. Van Slyke and White,^c in a study of the relation between the digestion and the retention of ingested proteins, found that squeteague is digested more slowly than either beef or cod. From the above facts it is fair to conclude that the tardy solution of the squeteague by trypsin shown by our data is not alone due to the absence of carbon dioxide, but is a consequence of the inherent nature of the protein itself.

^a White & Crozier, *op. cit.*

^b Schierbeck, N. P.: Ueber den einfluss der kohlensäure auf die diastatischen und peptonbildenden fermenten im thierischen organismus. Skandinavisches Archiv für Physiologie, bd. 3, s. 344-375, 1892. Leipzig.

^c Van Slyke, D. D. & White, G. F.: The relation between the digestibility and the retention of ingested proteins. Journal of Biological Chemistry, vol. IX, p. 219-229, 1911. Baltimore.

The amino nitrogen in solution increases of course with length of time. The average size of the peptids split off from the protein should be especially noted. From these data and the experiments of White and Crozier it is evident that the proteins studied break down into simple cleavage products practically as soon as they go into solution. At the end of a half hour's digestion the average size of the peptids is only 2.02; the cleavage products on the whole are indicated to be amino acids. The cleavage of certain proteins by trypsin has been intimately studied, and it is known that

$\frac{100 \times \text{soluble nitrogen}}{100 \times \text{total nitrogen}}$

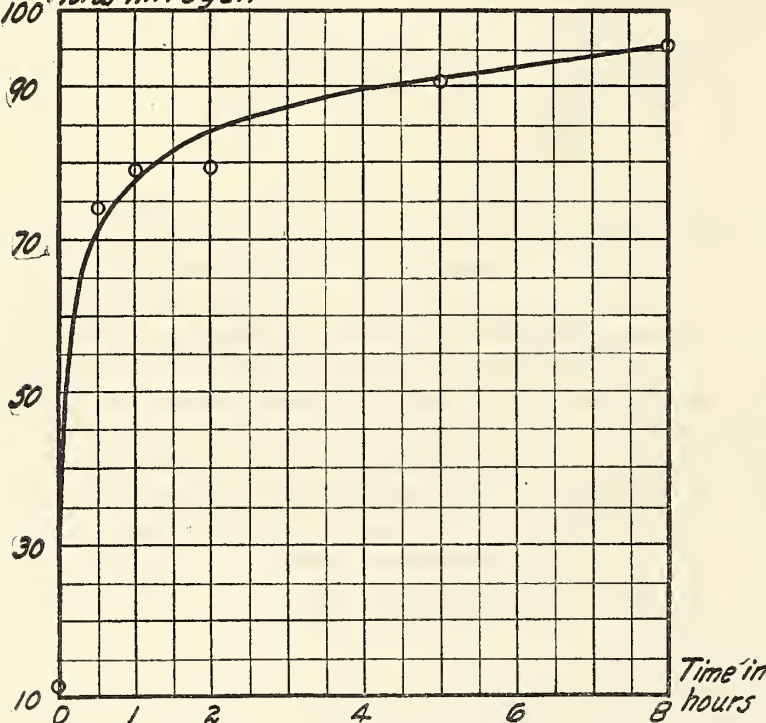


FIG. 1.—Change of the per cent of soluble nitrogen of the total nitrogen during the time of proteolysis.

work which, as just mentioned, has shown that there are certain substances which resist the hydrolytic action of trypsin altogether. The increase in the proportion of amino nitrogen during the eight hours' digestion is very slight, and we must conclude, therefore, that the cleavage of the meat, while yielding amino bodies of a simple nature, leaves the greater part of the soluble nitrogen combined in substances which are extremely stable.

The same conclusions may be drawn from the results of our experiments involving Sørensen's method. In figure 2 the curves are of the same slope, although, of course,

some amino acids are readily formed, while others are produced slowly or not at all. The above results, however, show that the greater portion of the nitrogen in solution exists in bodies of exceedingly simple character. The significance of this physiologically can not be pointed out here, but will be reserved for future discussion.

The relation of the amino to the total soluble nitrogen is shown in figure 2. After eight hours' digestion only 28.35 percent of the nitrogen is in the amino form. This is a confirmation of earlier

only approximate figures are expected on assuming the presence of one amino group for every carboxyl group indicated by the sodium hydroxide required. The amino nitrogen thus estimated is regularly greater than that determined by the nitrous acid method, and the peptids as computed are about 1.5 times as large. It is possible that in such calculations this effect is produced by the presence of such monamino-dicarboxylic compounds as glutamic acid. The discrepancy in the results is not of such a magnitude as to prevent deducing rigid conclusions concerning the rate and course of digestion of such proteins as the one under investigation.

SUMMARY.

1. Sørensen's method for the determination of amino acids was applied to a study of the tryptic proteolysis of *Cynoscion regalis*. The results were regular and in accord with those obtained by the nitrous acid method for the analysis for

amino nitrogen. A practical method for the determination of the food value of proteins has therefore been developed.

2. The relatively low rate at which the protein is made soluble agrees with the results of metabolism experiments.

3. Very low cleavage products are formed as soon as the protein goes into solution, the average size of the peptids being 2.02 after a half hour's digestion.

4. There is a very stable nitrogen complex which is not attacked by trypsin.

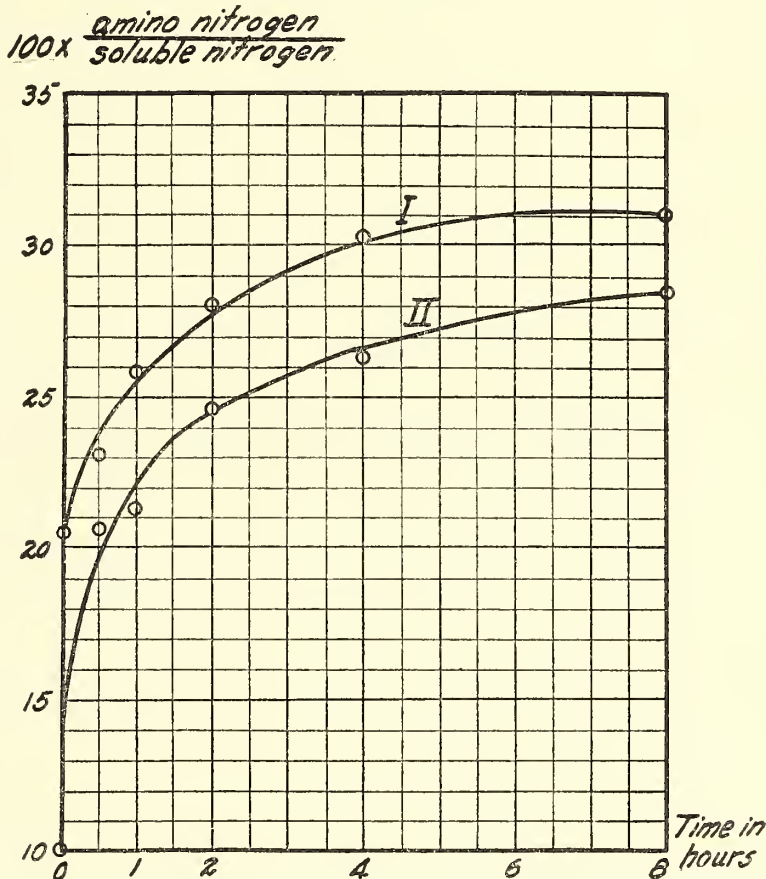


FIG. 2.—Change of the per cent of amino nitrogen of the soluble nitrogen during the time of proteolysis.

PROPERTIES OF FISH AND VEGETABLE OIL MIXTURES



By George F. White and Adrian Thomas

PROPERTIES OF FISH AND VEGETABLE OIL MIXTURES.

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In consequence of the increasing interest in the utilization of various fish oils for the most diverse commercial operations, their substitution where possible for the more valuable vegetable oils, and the lack of intimate and complete knowledge of their physical and chemical properties, it has seemed desirable to continue and extend the work which was carried out recently by one of us,^a on fish oils of known origin. The uncertainty of the various tests which have been applied to any oil to detect possible adulteration by another of inferior value has been due rather to the want of a full conception of the behavior of fish oils under all circumstances than any inherent difficulty connected with the problem. A careful study of mixtures of fish oils with each other and with vegetable oils should yield results of value to both analyst and manufacturer.

In this article there are presented the results of the analysis of dogfish liver (*Mustelus canis*), soya-bean, linseed, China-wood oils, and mixtures of these with each other. The fish oil was extracted from livers by steam pressure by the method previously described by one of us. Mixtures were made up by weight. The viscosity, density, index of refraction, saponification number, acid number, and iodine number were then measured according to the following description.

VISCOSITY AND FLUIDITY.

It has been shown that the fluidities of fish-oil mixtures are additive, and it should be expected that the same condition would obtain with all oils except in those cases where there is association, decomposition, or some other exceptionally disturbing factor. As the viscosity of an oil is of particular interest to the paint manufacturer, and fish oils are used largely for outside paints or to adulterate oils for other purposes, this property has therefore been especially considered in our study of these oils.

^a White, G. F.: A study of the viscosity of fish oils. The fluidity of fish oil mixtures as an additive property. *Journal of Industrial and Engineering Chemistry*, vol. 4, p. 106-110, and p. 267-270, 1912. Easton, Pa.

A viscosimeter capable of very accurate measurement gave satisfactory service in our previous work ^a and a new one was made and calibrated according to the method already given. Following are the constants obtained for this instrument:

Length of capillary (approximate).....	1.6 cm.
Volume of left limb.....	2.1310 c. c.
Volume of right limb.....	2.0748 c. c.
Pressure correction (30°), left limb.....	— 0.30 cm.
Pressure correction (30°), right limb.....	— .30 cm.
Ratio of r^4 to l.....	.00005835
	.00005822
	.00005837

The formula used for the calculation of the viscosity was

$$\eta = \frac{\pi r^4 p t}{8 v l} - \frac{v d}{8 \pi t l}$$

where η is the viscosity, r the radius, and l the length of the capillary, v the volume of liquid passing through the capillary, d the density of the liquid, p the pressure, and t the time of flow. As has been stated, the method of calibration and manipulation has been fully described in previous papers.

In the following tables are presented the results of the viscosity measurements, which were taken at 30°, 50°, 70°, and 90°, for the right and left limbs, the average of the two, and the reciprocal of the latter value, which is the fluidity. The China-wood oil was measured at 35° and the value at 30° extrapolated from the curve, as the oil was so viscous at the lower temperature that the time necessary for a determination was very long. The pure oils were cooled after measurement at 90° and the viscosity redetermined at 30° to note any possible change due to chemical decomposition.

TABLE I.—DOG-FISH-LIVER OIL.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
<i>Degrees.</i>				
30	0.4143	0.4140	0.4142	2.414
50	.2113	.2110	.2112	4.735
70	.1247	.1247	.1247	8.020
90	.08046	.08063	.08055	12.41
30	.4142	.4142	.4142	2.414

TABLE II.—LINSEED OIL.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
<i>Degrees.</i>				
30	0.3312	0.3311	0.3312	3.019
50	.1757	.1757	.1757	5.692
70	.1071	.1069	.1070	9.346
90	.07103	.07119	.07111	14.06
30	.3312	.3310	.3314	3.016

^a White, G. F., op. cit.

TABLE III.—SOYA-BEAN OIL.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
<i>Degrees.</i>				
30	0.4067	0.4058	0.4063	2.461
50	.2060	.2065	.2063	4.847
70	.1207	.1209	.1208	8.278
90	.07807	.07836	.07822	12.79
30	.4069	.4067	.4068	2.458

TABLE IV.—CHINA-WOOD OIL.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
<i>Degrees.</i>				
30	.....	.....	1.859	0.5379
35	1.591	1.587	1.589	.6293
50	.7796	.7805	.7801	1.282
70	.3699	.3717	.3708	2.697
90	.2126	.2128	.2127	4.702
35	1.933	1.957	1.946	.5139

TABLE V.—DOGFISH-LIVER AND LINSEED OIL MIXTURES.

25 PER CENT LINSEED.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
<i>Degrees.</i>				
30	0.3954	0.3943	0.3949	2.533
50	.2027	.2018	.2023	4.943
70	.1204	.1201	.1203	8.313
90	.07784	.07798	.07791	12.84

50 PER CENT LINSEED.

30	0.3712	0.3712	0.3712	2.694
50	.1930	.1925	.1928	4.694
70	.1150	.1152	.1151	8.688
90	.07554	.07561	.07558	13.23

75 PER CENT LINSEED.

30	0.3555	0.3556	0.3556	2.812
50	.1866	.1866	.1866	5.354
70	.1123	.1124	.1124	8.897
90	.07425	.07427	.07426	13.47

TABLE VI.—DOGFISH-LIVER AND SOYA-BEAN OIL MIXTURES.

25 PER CENT SOYA BEAN.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
<i>Degrees.</i>				
30	0.4121	0.4125	0.4123	2.425
50	.2121	.2094	.2108	4.744
70	.1234	.1227	.1231	8.123
90	.07952	.07934	.07941	12.59

50 PER CENT SOYA BEAN.

30	0.4099	0.4130	0.4115	2.430
50	.2074	.2082	.2078	4.813
70	.1215	.1227	.1221	8.190
90	.07930	.07954	.07942	12.59

75 PER CENT SOYA BEAN.

30	0.4074	0.4071	0.4073	2.455
50	.2072	.2075	.2074	4.822
70	.1210	.1214	.1212	8.251
90	.07852	.07865	.07859	12.72

TABLE VII.—DOGFISH-LIVER AND CHINA-WOOD OIL MIXTURES.

50 PER CENT CHINA WOOD.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
<i>Degrees.</i>				
30	.....	.....	0.7950	1.258
35	0.6926	0.6942	.6934	1.442
50	.3895	.3875	.3885	2.574
70	.2085	.2080	.2083	4.801
90	.1258	.1259	.1259	7.943

The viscosity and fluidity are pictured graphically in figures 1 to 3. According to Bingham's fluidity hypothesis,^a the fluidities of liquid mixtures should be additive when there is no association or action between the components. This is true when the fluidity-temperature curve is linear. It may be seen from figure 2 that the fluidities of dogfish, linseed, and soya-bean oils are nearly linear functions of the temperature and their curves have the same slope.

Figure 3 shows that mixtures of these oils have fluidities which are linear functions of the composition. On the other hand, China-wood oil behaves differently. Its

^a Bingham, E. C. and Harrison, J. P.: Viskosität und fluidität. Zeitschrift für physikalische Chemie, bd. 66, p. 1-32, 1909. Leipzig.

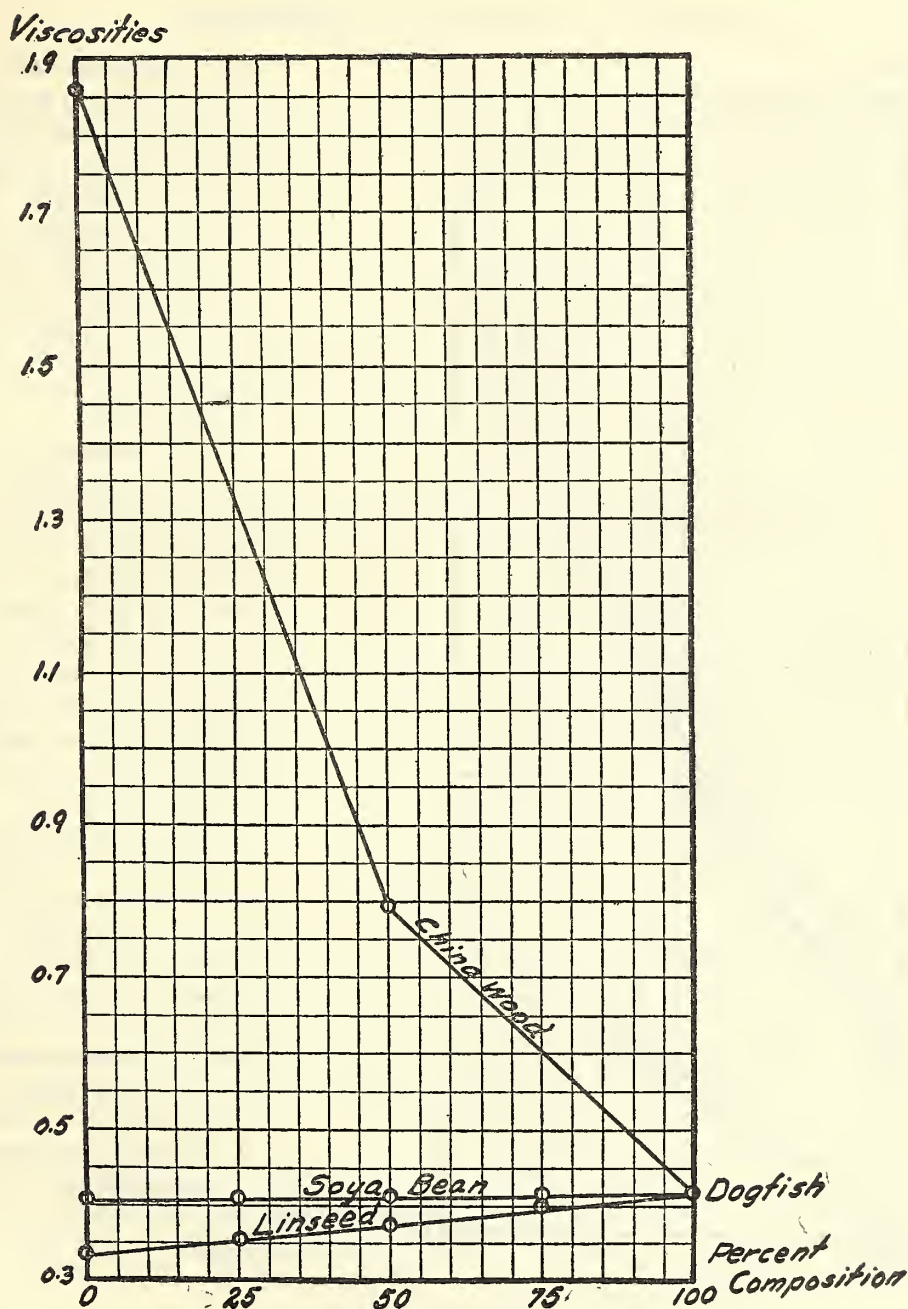


FIG. 1.—Viscosity Curves, 30°.

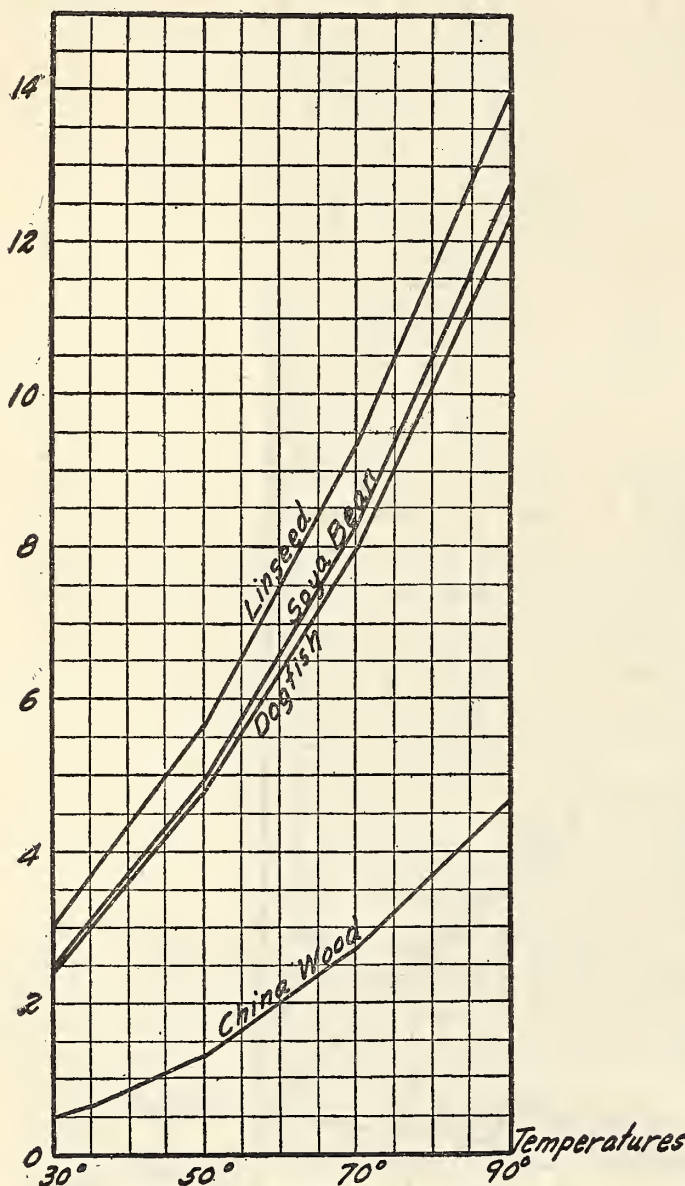
Fluidities

FIG. 2.—Fluidity curves, 30°–90°.

fluidity curve does not have the same slope as those of the other oils, and also its fish-oil mixtures do not give additive fluidities. The data in table IV show that it changes in composition on being heated to 90° since its viscosity at 35° changes from 1.589 to 1.946. The values for the other oils remain constant.

It is interesting to note how much more viscous is the China-wood oil than the other three oils, this property being a good test of its purity, since a little adulteration by other oils of viscosity approximating the others would lower the viscosity of the China-wood oil markedly.

The viscosity curves of the mixtures are given for 30° in figure 1. As has been shown before, the linear curves obtained for soya-bean oil and linseed oil mixtures were to be expected, since the viscosities of the components are nearly identical. Neither the viscosity nor the fluidity curves for the China-wood oil mixtures are linear.

DENSITY.

There is little to be said in regard to the data furnished by specific gravity determinations. These were made by use of the Ostwald pycnometer. The results are given in table VIII and shown by graphs in figures 4 and 5. Figure 4 shows that the densities

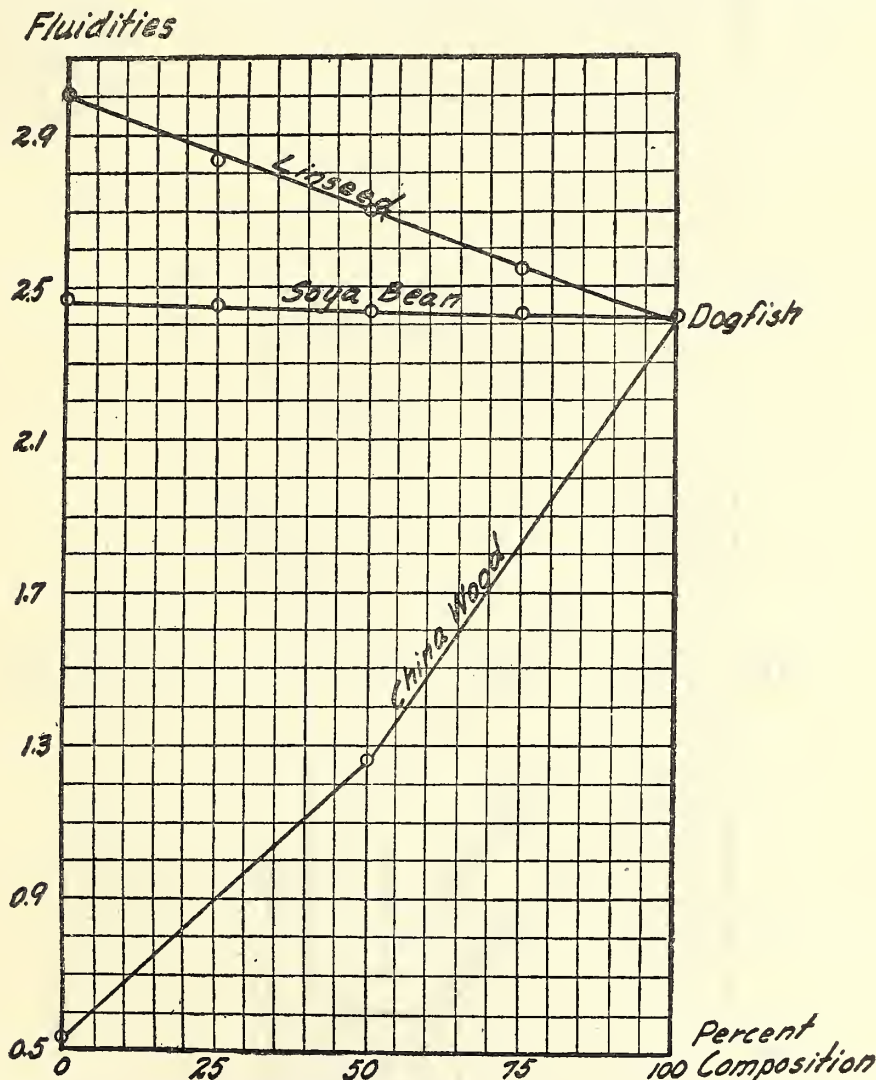


FIG. 3.—Fluidity curves, 30°.

are linear functions of the temperature over the range at which we worked, except with the China-wood oil, the composition of which changes on heating. Linseed and dogfish-liver oil mixtures have additive densities at 30° while the other mixtures do not. This data was of value to us principally in our calculation of the viscosities.

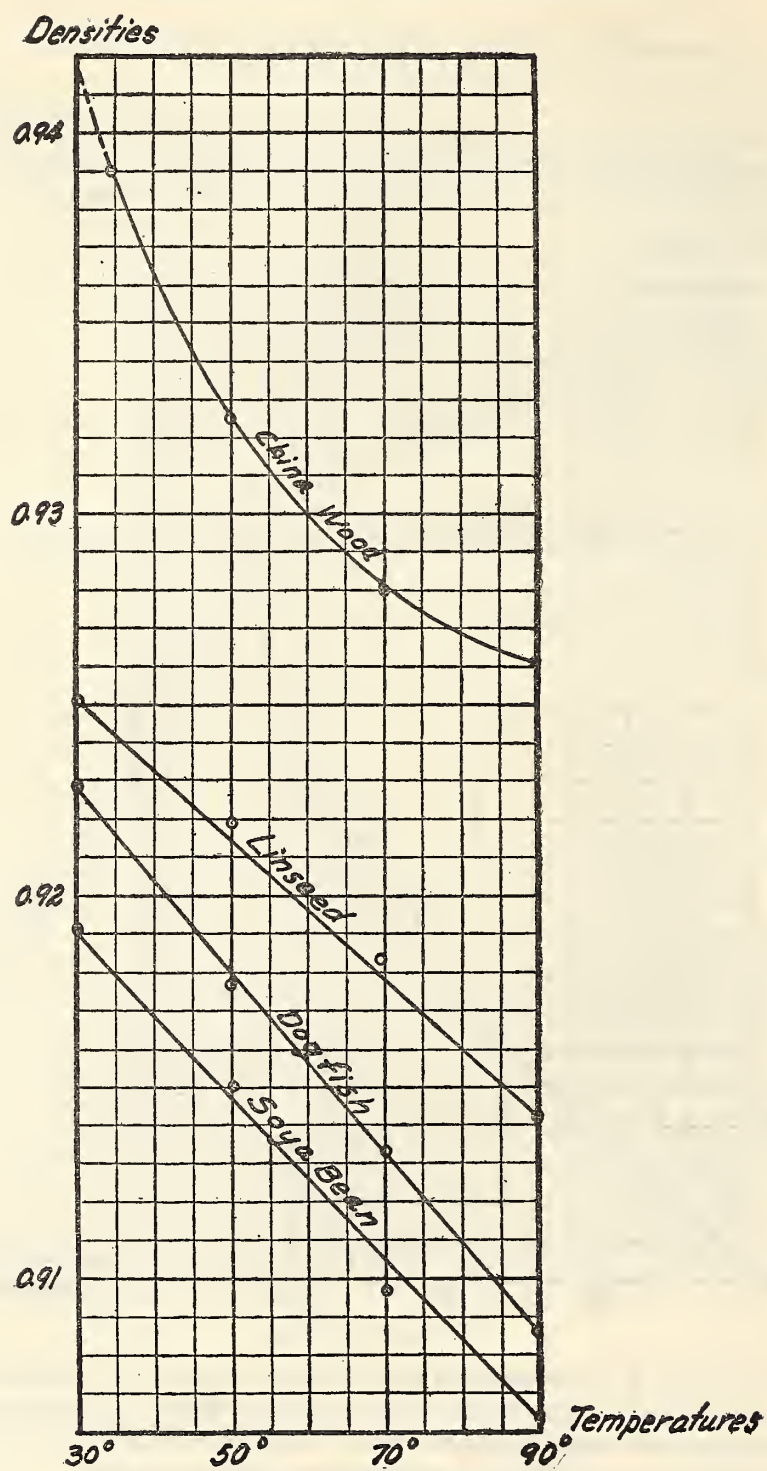


FIG. 4.—Density curves, 30°–90°.

TABLE VIII.—DENSITIES OF OILS AT GIVEN TEMPERATURES.

Oils.	30°	35°	50°	70°	90°
Dogfish-liver.....	0.9228		0.9175	0.9131	0.9082
Linseed.....	.9251		.9219	.9183	.9141
Soya-bean.....	.9191		.9149	.9095	.9063
China-wood.....	.9411	0.9389	.9324	.9279	.9260
Dogfish-liver:					
25 per cent linseed.....	.9237		.9158	.9120	.9090
50 per cent linseed.....	.9235		.9124	.9051	.8986
75 per cent linseed.....	.9245		.9169	.9100	.9051
25 per cent soya-bean.....	.9200		.9158	.9111	.9082
50 per cent soya-bean.....	.9200		.9149	.9076	.9055
75 per cent soya-bean.....	.9191		.9141	.9103	.9046
25 per cent China-wood.....	.9268	.9237	.9149	.9209	.9074
50 per cent China-wood.....	.9300	.9289	.9255	.9230	.9188
75 per cent China-wood.....	.9348	.9322	.9245	.9230	.9204

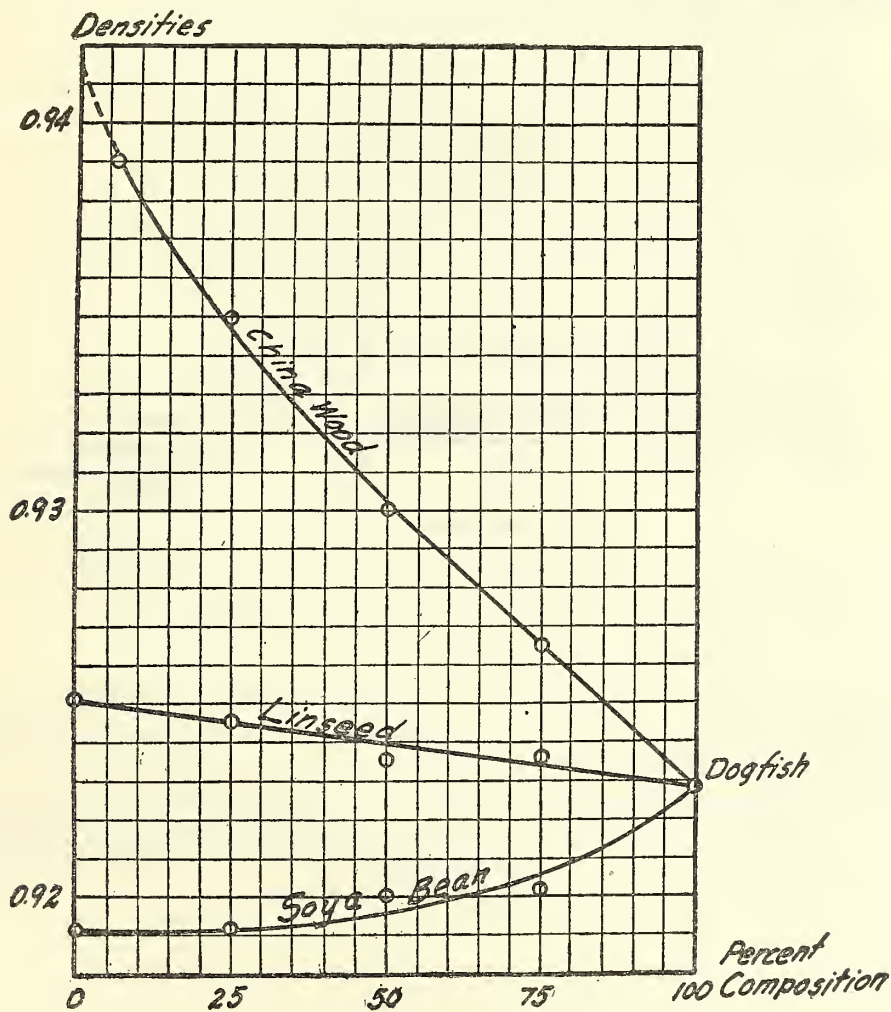


FIG. 5.—Density curves, 30°.

INDEX OF REFRACTION.

The refractive indices were measured by the use of a microscope, the apparent and true depths of a column of liquid being compared. Figure 6 shows that the index of refraction is not a good criterion of the purity of linseed and soya-bean oils when being tested for the presence of fish oil, but it should be valuable in the case of China-wood oil,

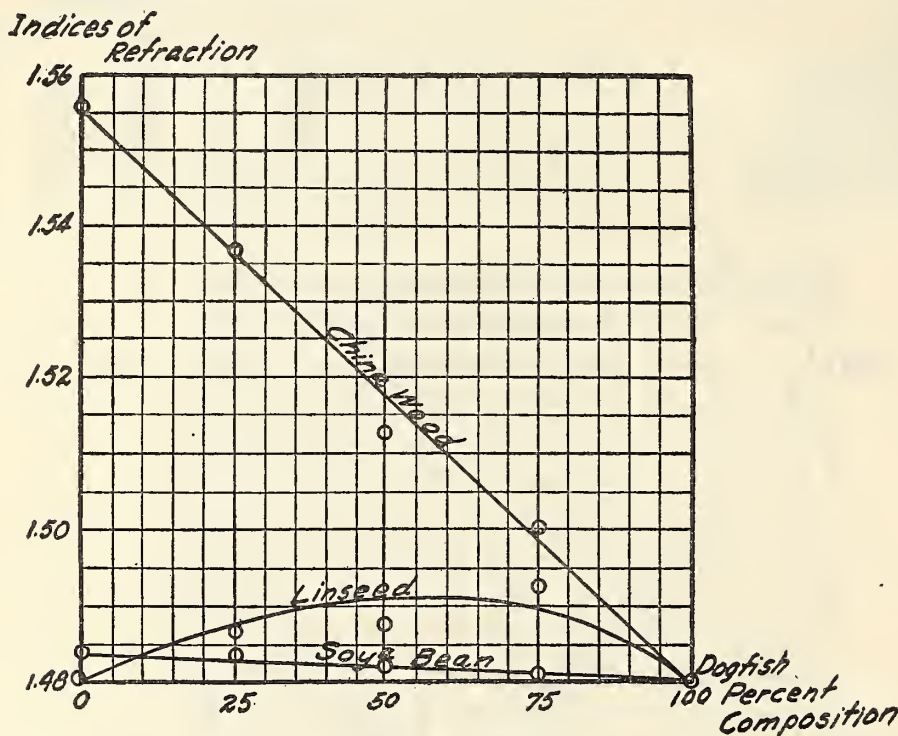


FIG. 6.—Index of refraction curves, 25°.

the refractive index of which is considerably greater than that of the other oils. This has been brought out by the work of Wise^a in a recent study of this oil.

ACID, SAPONIFICATION, AND IODINE NUMBERS.

The results of the acid, saponification, and iodine number measurements are presented in table IX and figures 7 to 9. The first two numbers represent the milligrams of potassium hydroxide necessary for 1 gram of oil, while the iodine numbers were obtained by Hübl's method, being per cent iodine required by the oil.

^a Wise, L. E.: On the indices of refraction of China-wood oil. *Journal of Industrial and Engineering Chemistry*, vol. 4, 1912, p. 497-498. Easton, Pa.

The acid numbers are seen to be additive generally for the mixtures, while the saponification numbers offer no general behavior. The iodine numbers are additive for

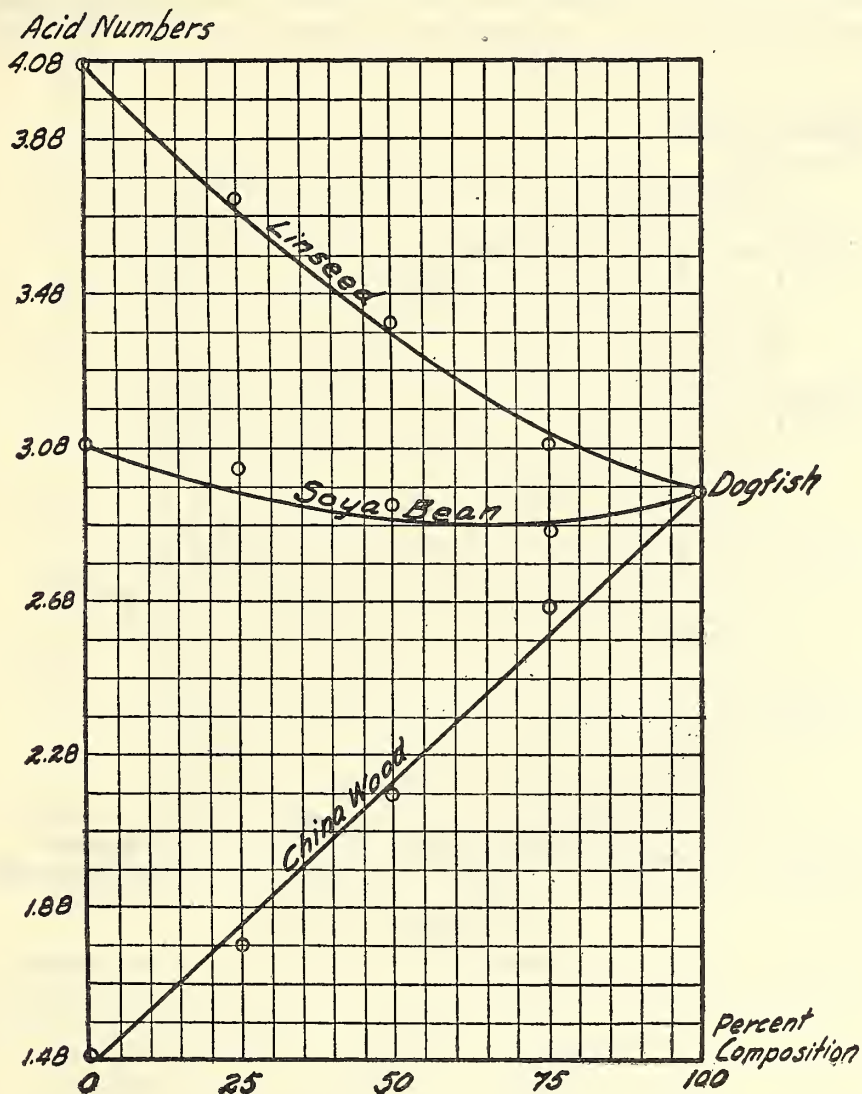


FIG. 7.—Acid number curves.

the linseed and soya-bean mixtures, the China-wood mixtures, however, giving a hyperbolic curve. As the iodine number of the linseed is so much higher than that of the dogfish-liver oil, this, as is well known, furnishes good evidence of the purity of the former.

The values for the other vegetable oils are so near those of the fish oil that great value can not be placed in this test. Reference may be made to the work of McIlhiney^a for a method of examining China-wood oil.

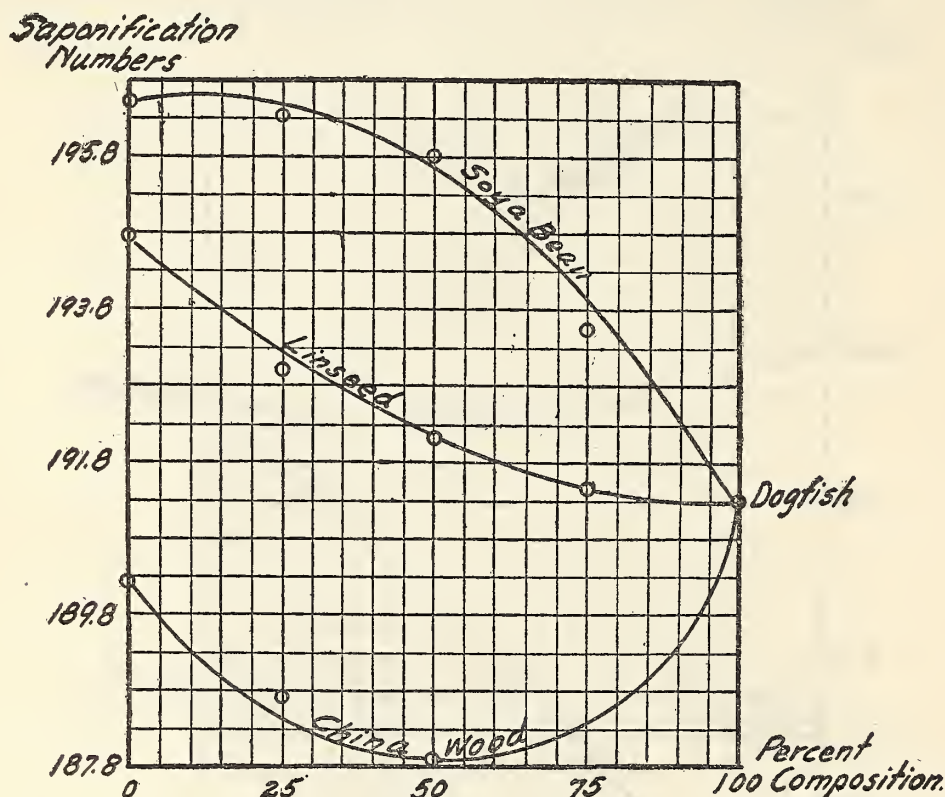


FIG. 8.—Saponification number curves.

TABLE IX.—INDEX OF REFRACTION, ACID, SAPONIFICATION, AND IODINE NUMBERS.

Oils.	Index of refraction at 25°.	Acid number.			Saponification number.			Iodine number.		
		1	2	Average.	1	2	Average.	1	2	Average.
Dogfish-liver.....	1.4801	2.91	2.94	2.93	191.3	191.2	191.3	122.7	120.3	121.5
Linseed.....	1.4805	3.98	4.01	4.00	194.0	195.3	194.7	152.1	152.7	152.4
Soya-bean.....	1.4837	3.08	3.08	3.08	196.7	196.4	196.5	130.5	125.1	127.8
China-wood.....	1.5560	1.47	1.49	1.48	190.1	190.2	190.2 (124.4?)	137.1	137.1	137.1
25 per cent linseed.....	1.4948	3.06	3.06	3.06	191.4	191.6	191.5	129.2	.....	129.2
50 per cent linseed.....	1.4872	3.41	3.43	3.42	192.0	192.4	192.1	137.9	139.1	138.5
75 per cent linseed.....	1.4870	3.75	3.68	3.72	191.0	194.9	193.0	144.3	145.1	144.7
25 per cent soya-bean.....	1.4790	2.85	2.85	2.85	193.5	193.5	193.5	123.3	123.1	123.2
50 per cent soya-bean.....	1.4819	2.94	2.92	2.93	195.6	195.9	195.8	123.1	122.1	122.6
75 per cent soya-bean.....	1.4834	3.00	3.03	3.02	196.4	196.1	196.3	126.9	127.7	127.3
25 per cent China-wood.....	1.4997	2.60	2.72	2.66	193.2	193.0	193.1	128.0	126.4	127.2
50 per cent China-wood.....	1.5120	2.14	2.19	2.17	187.6	187.9	187.8	133.2	131.4	132.3
75 per cent China-wood.....	1.5363	1.78	1.76	1.77	188.5	188.9	188.7	135.6	136.5	136.1

^a McIlhiney: A method of examining China-wood oil. Journal of Industrial and Engineering Chemistry, vol. 4, 1912, p. 496-497. Easton, Pa.

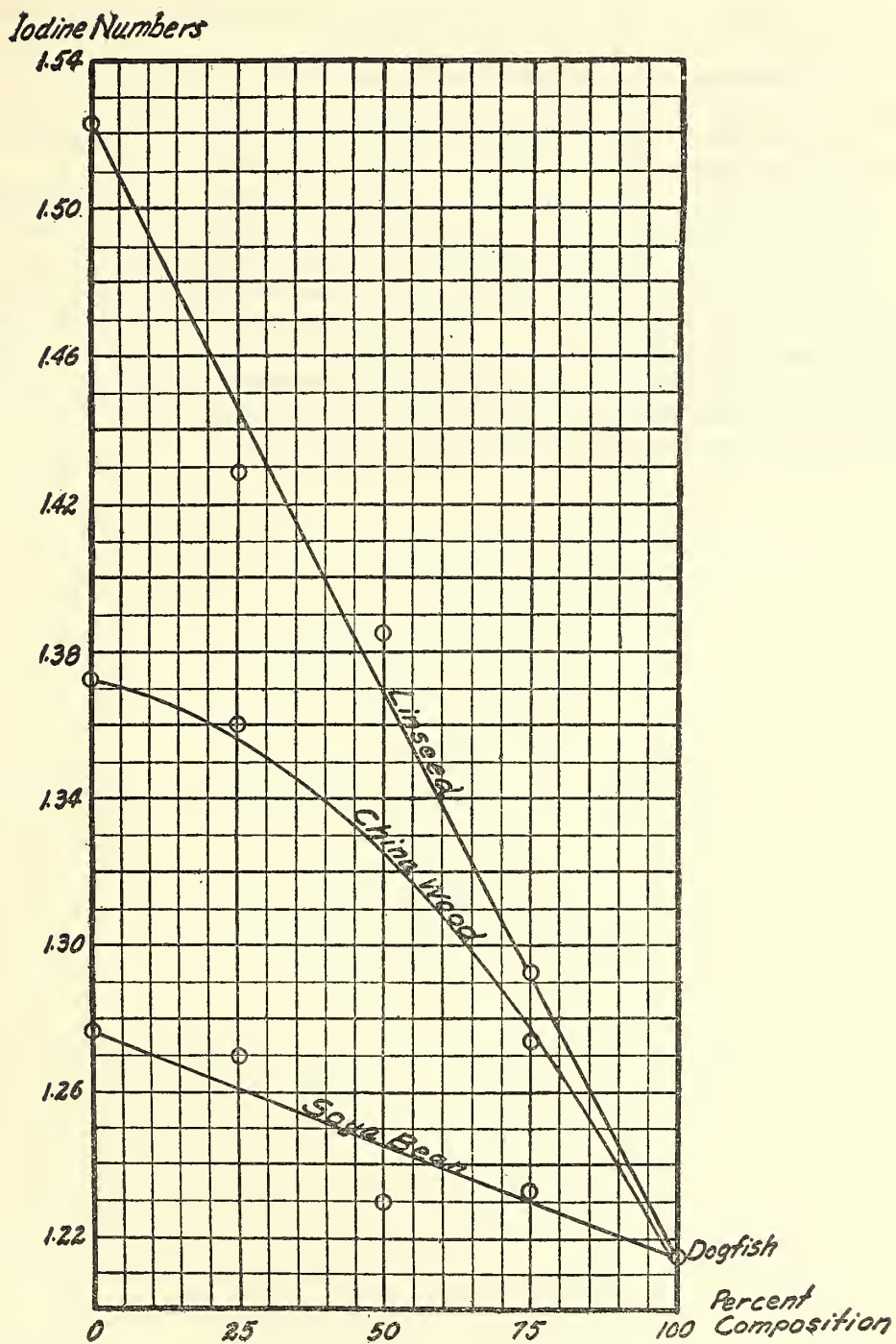


FIG. 9.—Iodine number curves.

SUMMARY.

1. The fluidities of fish and vegetable oil mixtures are additive, except where there is decomposition of either component on heating.
2. The viscosities of these mixtures are also additive when the values for the components approximate each other closely.
3. The fluidities of vegetable oils are nearly linear functions of the temperature. It has been previously shown that this holds true for various fish oils.
4. The fluidity of China-wood oil is a good test of its purity, as it is unusually low.
5. The specific gravities of the mixtures are approximately additive and vary linearly with the temperature. The density of China-wood oil is very high.
6. The index of refraction, acid number, and saponification number of the mixtures do not allow any general conclusions. The acid number of linseed oil is high and that of dogfish-liver oil is low compared with that of China-wood oil. The refractive index of China-wood oil is lowered by the introduction of small amounts of fish oil.
7. The low iodine number of the dogfish-liver oil makes the presence of this oil in vegetable oils known by marked lowering of their iodine values.

THE EFFECT OF WATER-GAS TAR ON OYSTERS



By Philip H. Mitchell

THE EFFECT OF WATER-GAS TAR ON OYSTERS.

By PHILIP H. MITCHELL.

For a number of reasons it has become desirable to know the effects of oily and tar-like wastes on marine life of economic importance. Damages have been claimed for pollution of oyster beds by wastes from the manufacture of gas. A report to the Rhode Island shellfish commission has attributed to water-gas tar harmful effects to oysters in Narragansett Bay.^a Tar of various sorts is used for coating piles or stakes, which might be in proximity to shellfish. Oily wastes are constantly escaping from passing craft in inland waters.

The present investigation does not cover the entire subject, but is confined to one important phase—the effect of water-gas tar on oysters. The experiments made during the summer of 1912 at the laboratory of the Bureau of Fisheries at Woods Hole could not then be carried further.

The tar was obtained from the separator at the works of the Providence Gas Co. on October 25, 1910, and was a mixture of the heavier and lighter tars as obtained in the manufacture of water gas, using an average temperature of 1,450° F. An analysis of tar taken under comparable conditions from the same separator at another time showed, according to the records of the Providence Gas Co., the following analysis:

	Per cent by volume.
Specific gravity at 65.5° F., 1.050.	
Water.....	7.65
Light oil at 200° F.....	13.95
Dark oil at 400° F.....	42.20
Medium pitch.....	36.20
Free carbon.....	2.70

Three series of experiments were made. In the first, oysters were exposed to water-gas tar in stagnant sea water; in the second series they were exposed to the tar in running sea water; while in the third small amounts of water-gas tar were introduced inside the shells of oysters.

SERIES I.

Experiment 1.—An oyster, marked with a file for identification, as were all the oysters used in these experiments, and weighing 83.2 grams, was put into a battery jar with 40 c. c. of water-gas tar and 2,500 c. c. of sea water. On the following day the water was changed by the method used in all the experiments of this series. A siphon delivered sea water from an aquarium to a point about 2 inches from the bottom of the jar, while another siphon at the same time drew off water from the middle of the jar. Water was allowed to run thus 10 to 15 minutes. As the tar stuck to the sides

^a Field, G. W. In Annual Report of the Commissioners of Shell Fisheries, Rhode Island, 1906, appendix D, p. 46-64.

and bottom of the jar, or, in the case of the lighter more oily portions, floated on the surface of the water, none, or very little of it, was removed while the water flowed through the siphons. The water, therefore, was almost completely changed without removing the tar. Shortly after the water had been changed the oyster was seen to be slightly open, but could close at the slightest jar. The water was changed in this manner once or twice daily for 10 days. The oyster was often seen partly open during this time, but would always respond to a mechanical stimulus by closing. After 10 days the water was no longer changed, but was left entirely stagnant. At the end of two weeks under these conditions the oyster seemed to be affected. It now remained continuously open, and appeared unable to close when stimulated. A few days later it showed signs of putrefactive disintegration.

Experiment 2.—An oyster weighing 63.7 grams was treated exactly as in experiment 1. The results were quite the same, except that when the water was left entirely stagnant disintegration set in after five days.

Experiment 3.—An oyster weighing 71.6 grams was treated as in the preceding experiments, except that the tar was smeared all over the inside of the jar and on the oysters. After 24 hours the oyster was found wide open and unable to close when stimulated. It was removed from the jar, and was seen to have its mantle greatly retracted. It would spring open when closed by hand. It was washed and put into an aquarium in running sea water. Two days later it appeared to be entirely recovered, as it would close normally when stimulated. It was then put back into the jar of sea water and tar in which it had been at first. It was now kept in this jar during six days, with the water changed once or twice daily. At the end of this time it had again lost the ability to close normally, but when put in the aquarium once more it again apparently recovered. About three weeks later, however, it became disintegrated.

Experiment 4.—An oyster weighing 95 grams was arranged exactly as in experiment 3. The results were quite the same, that is, after 24 hours it refused to close, but recovered when put in the aquarium of running sea water. Some weeks later, however, it died. That its death was due to the tar is not certain, because at that time other oysters in the same aquarium died without any previous exposure to tar.

Experiment 5.—An oyster weighing 78.7 grams was treated exactly as in the preceding experiment. It, too, became unable to close after 24 hours, and when put in running sea water entirely recovered. At the end of the summer, nine weeks later, it seemed entirely normal and had a normal appearance when opened.

Experiment 6.—An oyster weighing 62 grams was treated exactly as in the preceding experiment. The result was slightly different in that the oyster did not begin to show a tendency to remain open until after three days, and became entirely unable to close after five days in the tarry water with daily changing of the water. It was then put in running sea water and began to disintegrate a few days later.

Experiment 7.—An oyster weighing 70.8 grams was put into a battery jar with 20 c. c. of the tar not in contact with it and 2,500 c. c. of sea water. The water was changed daily during the next 10 days. It was then left stagnant during 8 weeks. The oyster was sometimes observed to be open, but would then close if jarred. At the end of that

time it was cleaned and dried and found to weigh 71.6 grams. It had formed new shell all around the edge. Opened it gave no smell of tar, the heart was beating and the mantle was normally sensitive to mechanical stimuli. Part of the heart and portions of the gills were discolored.

Control experiment.—An oyster weighing 72.4 grams was put in a battery jar with 2,500 c. c. of sea water. The water was changed during the next 10 days as in the preceding experiment and was then left stagnant during 8 weeks. Examination then showed no noticeable new shell, but the heart, gills, and mantle were quite normal.

The experiments of this series indicate that when considerable quantities of water-gas tar are in intimate contact with oysters in stagnant water serious or fatal effects are produced. Under these circumstances the oyster can not use its natural defense against a relatively or entirely insoluble substance. When the water is stagnant, there is little opportunity to eject such substances and free the organism from them. As will be shown later, the oyster can rid itself of water-gas tar when in running sea water. When the tar can not be ejected it seems to produce an effect similar to paralysis, so that the initial symptom is a failure of the adductor muscle to respond to stimulation of the sensory nerves. No conclusions as to the structures specifically affected can be drawn from these experiments. Whether the fatal effects produced in five of the above experiments were due to a direct toxic effect of water-gas tar, or to some indirect effect also, does not appear from these experiments.

SERIES II.

Method.—Two oysters were put in each of four battery jars. Each jar was arranged with two siphons, one bringing sea water from an aquarium to the jar with the lower end of the siphon about 2 inches below the level of water maintained by the other siphon, which carried water from the jar to a sink. The running water therefore tended to carry off the light floating oils but left the heavier tar sticking to the bottom and sides of the jar. The siphons were so arranged that each jar contained constantly about 2,500 c. c. of sea water. Into each jar there were put 30 c. c. of water-gas tar mixed with sand and thoroughly smeared over the bottom and sides of the jar and on the shells of the two oysters. From time to time during the following weeks small amounts of tar were added to replace that carried away by the siphons. After remaining in the jars as described during nine weeks the oysters were cleaned, weighed, and examined. Comparison of their weights at the beginning and at the end of the experiments is given in tabular form:

Jar.	Initial weight.	Final weight.
	<i>Grams.</i>	<i>Grams.</i>
1	98.0	99.0
	47.8	47.8
2	92.0	92.0
	52.4	52.3
	96.8	94.0
3	61.8	62.5
	101.1	100.7
4	45.2	44.3

That these variations in weight have no special significance is indicated by comparison with the variations in the weights of oysters kept in the aquarium during the summer but not exposed to tar.

Initial weight.	Weight after five weeks.
<i>Grams.</i>	<i>Grams.</i>
66.5	66.0
76.0	76.5
244.0	243.0
147.0	151.0

When opened all were found to be normal in appearance and function. No odor of tar was detectable in the shell contents of the oysters, although an abundance of tar was left in the jars at the end of the experiment. Smears of tar were also still present on the outside of the oyster shells.

These experiments indicate that even intimate contact with water-gas tar does not injure oysters in the course of nine weeks, provided facilities for defense in the form of moving water frequently renewed are available.

SERIES III.

Experiment 1.—A small oyster was first pried open and injected with 0.5 c. c. of water-gas tar. It was then put in a jar of running sea water. It remained tightly closed during the next two hours. On the next day it was found to be quite normal. It was open and apparently feeding, but closed when stimulated. Drops of tar near it indicated that the foreign material had been ejected. One week later it still appeared entirely normal. It was then again injected with 0.5 c. c. of tar, and was now put in stagnant sea water. Four days later it did not, when stimulated, close as readily and tightly as a normal oyster. It was then opened and found normal in its heartbeat and in contractility of the bivalve muscle, but the mantle was not normally responsive to mechanical stimulus.

This experiment indicates that when an oyster ingests tar and can not get rid of it because the surrounding water is stagnant, some impairment of the sensory apparatus in the mantle results. This interferes with certain activities of the oyster, prevents normal closure, and eventually causes degeneration of muscular and other tissues.

Experiment 2.—Three medium-sized oysters were each injected with about 1.5 c. c. of water-gas tar and then put in separate jars of running sea water. Some time after they were seen in each case to open slightly and in a few minutes close violently so as to eject masses of tar. This process was repeated a number of times in the course of one to three hours after injection. They then remained constantly closed for some time, but were found normally open on the following day. They were left in the running sea water for a period of eight weeks and behaved throughout that time like control oysters in the aquarium. As it was then necessary to terminate the experiments, the oysters were

opened and carefully examined. They were found to be normal in color, odor, heartbeat, responsiveness of the mantle, ciliary movement, and in short in every respect.

This experiment distinctly indicates that water-gas tar in considerable doses is harmless to an oyster in running sea water. The conditions of this experiment more closely resemble those of the native habitat of the oyster than do those of the preceding experiment, because tides and other currents over oyster beds maintain a constant movement and a continuous changing of the surrounding medium.

Experiment 3.—A medium-sized oyster was injected with 1 c. c. of water-gas tar, which was distributed all around the mantle. It was then put into about 1,500 c. c. of sea water and carefully observed. During the next five hours it did not visibly open and no tar escaped from it. On the following day, however, a few drops of tar were floating on the surface of the water. During the next two days the oyster was only infrequently observed and was not seen open, but on the third day it was found normally opened and able to close when stimulated. It was left in the same sea water during the next two weeks. It had then developed the usual symptoms of imperfect closure and when opened did not show a normally beating heart or a responsive mantle. This experiment confirms the first one of this series.

EFFECT OF WATER-GAS TAR ON THE DISSOLVED OXYGEN OF SEA WATER.

It seemed possible that tar and similar substances might in a measure reduce the oxygen content of water so as to affect shellfish. Mixtures of tar and sea water were, therefore, allowed to stand for varying periods of time and then tested by Winkler's titration method to measure the quantity of dissolved oxygen in the water. The experiments are summarized in the following table. Three liters of sea water were used in each case.

Amount of water-gas tar used.	Time mixture was allowed to stand at room temperature.	Oxygen remaining in water at end of the time.
<i>Cubic centimeters.</i>	<i>Hours.</i>	<i>Parts per million.</i>
200	20	6.61
200	24	6.10
200	45	.00
200	130	.08
50	40	2.71
50	45	1.10
50	130	.08
None.	40	a 7.10
None.	45	a 8.09
None.	130	a 8.26

a Control, sea water alone.

These experiments show that the tar can cause the disappearance of dissolved oxygen in sea water. How potent a factor this may be in causing the effects of the tar on oysters in stagnant water it is not, however, safe to say. Oysters, as the author has shown, are remarkably resistant to lack of oxygen and do not when deprived of it

show inability to close except in the advanced stages of oxygen starvation. That oxygen consumption by tar may help to account for the fact that oysters are injured by stagnant tarry water, while they are uninjured by the tar in running sea water, is quite probable. In the natural habitat of the oyster, however, it seems quite impossible that the slight reduction of dissolved oxygen which small amounts of tar could effect would alter the results of oyster culture.

CONCLUSION.

These experiments show no noticeable effects of water-gas tar on oysters in constantly renewed sea water. This is true in spite of the fact that large amounts of tar mixed with stagnant sea water, or small amounts injected into oysters which are kept in stagnant water, do cause serious or fatal effects. Considerable quantities (1.5 c. c.) may be put inside the shell of an oyster kept under conditions resembling those of its natural habitat without causing any effect. The harmlessness of the tar under these circumstances is due apparently to the ability of the oyster to rid itself of such foreign matter. In stagnant water the organism can not be effectively washed out, and effects involving a loss of sensitiveness in the mantle result. That consumption of the dissolved oxygen in the stagnant water by tar may have some effect on oysters is a possibility.

THE OXYGEN REQUIREMENTS OF SHELLFISH



By Philip H. Mitchell

THE OXYGEN REQUIREMENTS OF SHELLFISH.



By PHILIP H. MITCHELL.



The respiratory exchanges in lamellibranchs seem not to have been investigated. Probably the most notable work related to it is that of Vernon.^a He measured the oxygen utilization and carbon dioxide emission in a large number of marine forms, including certain Mollusca but no lamellibranchs. He showed that in the lower marine forms investigated, including Coelenterata, Tunicata, and Mollusca, the respiratory exchange was very small compared to the higher ones, for example, teleosts. There were, however, certain exceptions to this rule, notably the protozoan *Collozoum inermis*, which showed nearly as high a respiratory exchange as the fishes. He found also that, in general, the respiratory activity was more readily responsive to temperature in the lower than in the higher forms. He further showed that the gaseous exchange was relatively greater in the small than in the large individuals of the same species and found that, in general, the same distinction held between small and large species. The transparent pelagic animals were shown to have a very small proportion of solid organic matter in their tissues, so that calculated on that basis their respiratory activity was very large, greater indeed than fishes, amphibians, or even mammals.

In the present work some of those findings have been confirmed for the lamellibranchs. They show a ready responsiveness to temperature changes, a smaller utilization of oxygen in proportion to the body weight with increase in size, and those forms which showed a low oxygen requirement in relation to their entire weight showed a higher utilization in proportion to their dried weight.

The resistance to lack of oxygen in forms which have no power of locomotion is an important factor in adverse conditions. This is especially true of the edible shellfish, which, because of enforced closure during cold weather, or in the presence of polluted or roily water, or in water whose oxygen has been lowered by the presence of certain wastes or an abundance of life, must at times be deprived of their normal supply of oxygen. The subject therefore possesses an economic significance, and it was, in fact, the possibility that certain manufacturing wastes, removing oxygen from sea water, might therefore cause the death of oysters and clams which first directed the writer's attention to the subject. The particular wastes involved were those of gas works con-

^a Vernon, H. M.: Respiration in marine forms, *Journal of Physiology*, vol. XIX, 1895, p. 18.

taining at least traces and sometimes significant quantities of water-gas tar and other oily matter. The results of this investigation indicate, in a word, that the tar or oily wastes could have no effect on shellfish in this way. The details of this part of the work, however, are reserved for a report dealing specifically with the effect of water-gas tar on oysters. This paper is confined to oxygen requirements of shellfish and their resistance to lack of oxygen.

METHOD OF EXPERIMENT.

The method of manipulation was, in brief, to place the shellfish in a desiccator completely filled with sea water of known content of dissolved oxygen, leave the apparatus at some constant temperature during a definite period, and then to sample the water in the desiccator so as to compute its decrease in dissolved oxygen. Winkler's well-known titration method was used to measure the oxygen both at the beginning and end of each experiment. A vacuum desiccator was used for the containing vessel because it could easily be closed water-tight, could accommodate almost any size of shellfish, and enabled one to take through the side opening with glass stopcock a fair sample of the contents.

In practice a number of precautions were found necessary. The hollow dome of the desiccator cover was entirely filled with paraffin to exclude air from entrapment in it. A glass tube within the desiccator was connected to its side stopcock and reached nearly to the bottom. When, therefore, the filled desiccator was opened at the top water could be sucked off through the opened side cock into the sampling bottle so that the sample would come from a point well below the surface of the water, where the oxygen content would be fairly constant. The sea water ^a used in each experiment was brought to the required temperature and placed in a large reservoir jar on a shelf, from which it could be siphoned without bubbling into the desiccator. When it was thus nearly filled, an oyster was gently placed on a glass tripod, where it would rest near the center of the desiccator. With clams it was found necessary to leave them in the desiccator submerged in water for a few hours before the experiment, because, unlike oysters, they would not open quickly after they had been handled. In either case, though, water from the shelf reservoir was siphoned into the overflowing desiccator for sufficient time to bring the oxygen content to approximate constancy and then the cover was put on, leaving just opening enough to admit the siphon tube.

The side cock of the desiccator was then connected by rubber tubing to the sampling bottle, and after starting by suction the water was allowed to siphon through the bottle two to three minutes. This period was found quite sufficient to give reliable duplicate results for water containing any percentage of oxygen measured in these experiments. The water running into the desiccator meantime was in excess of that running into the bottle, so that an overflow was maintained from the top of the desiccator and the sample rendered as fair as possible. At the exact second recorded as the beginning of the experiment the side stopcock was closed, the siphon quickly withdrawn from the desiccator,

^a From aquarium of running sea water, a part of the aquarium system of the laboratory.

and its lid put completely on, excluding bubbles. The entire apparatus was then kept in a bath of sea water whose temperature was maintained approximately the same as the water within the desiccator. The oxygen in the sample was meantime measured by titration.

After a period, usually about an hour in length, the desiccator was two or three times inverted to render its contents uniform and to stimulate the shellfish to close and thus stop using oxygen. The exact time of the first rough movement of the apparatus was recorded as the closing time of the experiment. The outside of the desiccator was then dried with a towel and the entire apparatus weighed. When currents in the water had come practically to rest, the side stopcock was again connected to the same sampling bottle used at the beginning of the experiment and a sample taken as before. Since the capacity of the desiccators was sufficient for 1,200 grams of water, even with the large shellfish, and as the sampling bottles held approximately 300 grams, it is plain that water could run through the sampling bottle some time without emptying the desiccator. The stream indeed was allowed to run at least two minutes. The capacity of the desiccators was not enough to permit of taking a duplicate sample that would be reliable, but this was not necessary because there is little chance of error in the Winkler's titration.

The last step in the process was to empty the desiccator completely, dry it and the shellfish, and weigh them together. This gave a means of determining by difference the weight of the water. It was probably accurate to within 2 grams. As the dissolved oxygen of the water both at the beginning and the end of the experiment was calculated in parts per million, it was only necessary to multiply the weight of water used by the decrease in its oxygen content expressed in parts per million and divide the result by 100 to find the decimilligrams of oxygen used by the shellfish. Experiment showed that no correction for change in the oxygen content of the water due to microorganisms or physical factors was, under the circumstances of constant temperature, etc., necessary. Results were expressed in decimilligrams of oxygen per hour and in most cases also computed in decimilligrams per hour per 100 grams of shellfish and in some cases in decimilligrams per hour per 1 gram of the dried weight of the total shell contents of the organism.

A formula for the first of these three computations might be expressed, therefore, as follows:

$$A = W \frac{a' - a''}{100} \cdot \frac{60}{t}$$

where A is the decimilligrams of O used per hour, W the weight, in grams, of water in the desiccator, a' the parts per million of oxygen in the first sample and a'' in the second sample, and t is the time of the experiment in minutes.

Throughout the experiments it was found necessary to observe the animal at frequent intervals, and if the shells closed up to discard the experiment, or if the shells closed only after a considerable number of minutes had elapsed to terminate the experiment immediately. This precaution was necessary because, as is well known, certain of the shellfish used in this work can close water tight and in that condition take from the

water, as will be shown below, no oxygen except the very small amount absorbed by their shells.

It appeared early in the work that constancy of results was exceedingly difficult to obtain. This was due to a variety of causes, chief of which was the great variability in the openness of the shells, for not only could the oyster or clam entirely or at least obviously close so that the experiment had to be terminated, but it could partially and unnoticeably close or indeed fail to open wide even from the beginning of the experiment. For the oyster, at least, the author succeeded in demonstrating this by graphic records. One shell of an oyster was connected by tying a string to the projections with a lightly balanced lever recording on a slow kymograph. As soon as the oyster in a water bath at a temperature between 18° and 20° C. had opened somewhat, the kymograph was started and the temperature of the bath raised at the rate of 1° C. in about eight minutes. The oysters remained fairly well open with brief periods of partial closure as the temperature increased to about 22° C. At that point there invariably appeared in the three individuals observed periods of maximum openness lasting as long as no disturbing factor intervened. Sufficient stimulus for partial closure, however, was likely to occur frequently. A light tap on the table or water bath, a heavy step in the room, the slamming of a door in a neighboring part of the building, or, indeed, any slight jar was surely registered by some movement of the shell. As the temperature increased up to about 26° or 27° C., the effect of these stimuli was much less marked. The oysters then maintained their maximum openness very persistently. Between 27° and 30° a tendency to very slow and incomplete opening after closure was noticeable, indeed no maximum openness was seen. At about 30° or 31° C., the oysters closed tightly, even if no mechanical stimulus was given.

As the kymograph method served to detect movements of the shell not noticeable to unaided observation and also slight openings of the shell not otherwise visible, these experiments were an aid to planning and interpreting measurements of oxygen utilization. They showed that below 19° C. and above 26° C. observations on the opened oyster were impossible, that temperature must be maintained constant throughout the experiment, and mechanical disturbances must be avoided as far as possible. A further source of difficulty had also to be overcome. When the oyster excreted it closed violently, to drive the fecal matter out of the shell. If the position of the animal rendered complete excretion difficult, closures were frequently repeated, and sometimes the oyster shut up tightly. It was necessary, therefore, to lay the oyster in the desiccator tipped so that the more concave side of the shell, where excretion occurs, would be lower than the other.

In spite of all precautions, however, perfectly consistent results could not always be obtained. Under the same or comparable conditions of temperature, oxygen content of the water, and physical conditions, the same individual would sometimes in different experiments give results disagreeing beyond the limits of the calculated, probable, experimental error. Various observations make it seem likely that the nutritive condition of the individual could account for some, at least, of these discrepancies. Thus, after

remaining at a high temperature (e. g., 24° – 26° C.) for some time, the oxygen requirement at a slightly lower temperature would tend to be greater than if the shellfish had been at a lower temperature before the experiment. If an oyster had been out of water for some time before the measurement, more oxygen would be used, generally, than if the specimen were left in the aquarium until the time of the experiment. After the shellfish had been kept in the aquarium some weeks they tended to use less oxygen than when taken recently from their native environment. Exceptionally an individual would show a high utilization of oxygen out of proportion to previous measurements and lasting for several days. As many of the interfering conditions as possible were, of course, eliminated, but still it seemed necessary to make a considerable number of experiments and draw conclusions only from averages. More than 350 measurements were made under various conditions on three types of lamellibranchs—the oyster (*Ostrea virginica*), the soft-shell or long clam (*Mya arenaria*), and the quahog or round clam (*Venus mercenaria*).

RESULTS.

OXYGEN REQUIREMENTS OF THE OYSTER.

Three series of experiments, each made on a limited number of individuals, are submitted. Although the results can scarcely be taken to show any seasonal variation, they are grouped, for convenience, according to the time they were carried out. In table I are the results of measurements taken during July, 1911; in table II, those of July and August, 1912; and in table III are results obtained during the latter part of August, 1912.

In the experiments of table I definite temperatures were not previously chosen and carefully adhered to as in the later work. The results, therefore, are here grouped for comparison as follows: All measurements taken at temperatures between 20° and 21.3° C. appear in one column, those at 21.5° to 23.5° C. in another, and those between 26° and 28° C. in a third. Where two or more experiments were made with one oyster at temperatures within a given range the average of the results is placed in parentheses. In the last three columns are the averages of comparable experiments computed as the decimilligrams of oxygen used per hour per 100 grams of oyster. By weight of oyster is meant in this and other tables not otherwise specified the weight in grams taken after it was closed under water, wiped as dry as possible with a towel, and left to dry in the air not more than half an hour. Such weighings were shown by duplication to be accurate to within two-tenths of a gram.

In table II are the results of experiments performed at definite chosen temperatures so controlled that the variation was not more than half a degree centigrade in any single experiment. The first five columns of results show the decimilligrams of oxygen used per hour at five temperatures by nine oysters. The averages of all comparable experiments are put in parentheses. The last five columns contain the averages, expressed in decimilligrams, of the oxygen used per hour per 100 grams of oysters.

TABLE I.—OXYGEN USED BY OYSTERS.

NOTE.—Figures in parentheses are averages of experiments under approximately uniform conditions.

Weight of whole oyster.	Decimilligrams of oxygen used per hour.			Average decimilligrams of oxygen per hour per 100 grams of oyster.		
	At 20° to 21.3° C.	At 21.5° to 23.5° C.	At 26° to 28° C.	At 20° to 21.3° C.	At 21.5° to 23.5° C.	At 26° to 28° C.
<i>Grams.</i>						
42.0	.....	5.6 9.0 7.8 6.8 (7.3)	.....	.....	17.4	.....
56.6	.....	11.8 7.6 (9.7)	.....	.....	17.2	.....
85.0	9.4 14.7 14.0 (12.7)	.....	19.3 18.8 (19.1)	14.9	.....	22.4
106.0	10.1 15.6 (12.8)	19.4	22.9 22.9 26.2 (24.0)	12.1	18.3	22.6
113.0	14.6	18.2 16.1 (17.1)	.....	12.9	15.1	.....
127.0	12.7 13.6 15.7 (14.0)	21.8 21.5 19.0 21.2 (20.9)	.....	11.1	16.5	.....
141.0	.....	19.0 18.0 (18.5)	.....	.....	13.1	.....

TABLE II.—OXYGEN USED BY OYSTERS.

NOTE.—Figures in parentheses are averages of measurements under approximately uniform conditions.

Weight of whole oyster.	Decimilligrams of oxygen used per hour.					Decimilligrams of oxygen used per hour per 100 grams.				
	At 19.5° to 20° C.	At 21° to 21.5° C.	At 22° to 22.5° C.	At 24° to 24.5° C.	At 26° to 26.5° C.	At 19.5° to 20° C.	At 21° to 21.5° C.	At 22° to 22.5° C.	At 24° to 24.5° C.	At 26° to 26.5° C.
<i>Grams.</i>										
42.0	7.6 9.8 (8.7)	12.3 13.8 (13.1)	10.3 13.9 (12.2)	14.6	13.4 14.9 11.2 (13.1)	20.7	31.0	29.1	34.8	31.3
51.0	11.6 10.7 11.8 (11.3)	9.3 11.4 9.6 6.2 (9.6)	11.7 11.5 (11.6)	12.6 12.7 (12.65)	13.6	22.2	17.9	22.8	24.8	26.7
66.5	15.1 9.4 10.5 9.1 (11.2)	16.0 9.9 16.1 14.0 (14.0)	15.5 11.8 (13.7)	16.0	18.6 17.2 (17.9)	16.9	21.0	20.6	24.1	26.9
76.0	11.5 14.0 (12.7)	13.9 15.3 14.2 (14.5)	15.3 12.8 (14.05)	15.8 20.5 16.2 (17.5)	23.5 20.9 24.5 20.7 (22.4)	16.7	19.0	18.5	23.0	29.5
97.4	13.4	14.6	.....	18.0	22.1	13.8	15.0	.....	18.5	22.7
128.0	13.7 17.8 (15.75)	.....	17.9 25.9 18.6 18.4 (20.2)	25.9 19.8 (22.8)	24.8	12.3	.....	15.7	17.8	19.4
147.0	16.0 19.4 (17.7)	18.4 18.2 (18.3)	20.4 19.3 (19.8)	20.8 21.9 (21.3)	26.6 26.0 (26.3)	12.1	12.5	13.5	14.5	17.9
244.0	18.1 22.3 (20.2)	23.5 25.7 (24.6)	34.6 25.7 (30.1)	30.0 26.1 24.0 (26.7)	35.1	8.3	10.1	12.3	11.0	14.4
262.0	19.0	29.1 29.5 21.4 20.8 (25.2)	27.4 24.8 (26.1)	28.7 30.7 (29.7)	37.0	7.3	9.6	10.0	11.3	14.1
Average..	.....	.....	.....	.....	.....	14.5	17.0	17.8	20.0	22.5

In table III are the results of measurements at four chosen temperatures on four oysters. These experiments were all done within a few days after the oysters were taken from the beds and therefore serve to some extent as a control on the condition of the oysters used in the other series. The first columns of results show the decimilligrams of oxygen used per hour at the designated temperatures. The averages of comparable experiments are put in parentheses. The figures in the next four columns are obtained by computing the averages of the oxygen utilization per 100 grams of oyster. In the next column is the weight, in grams, of the shell contents of each oyster when dried to constant weight. The last four columns show average decimilligrams of oxygen used per gram of dried substance. The figures in these columns were corrected for the

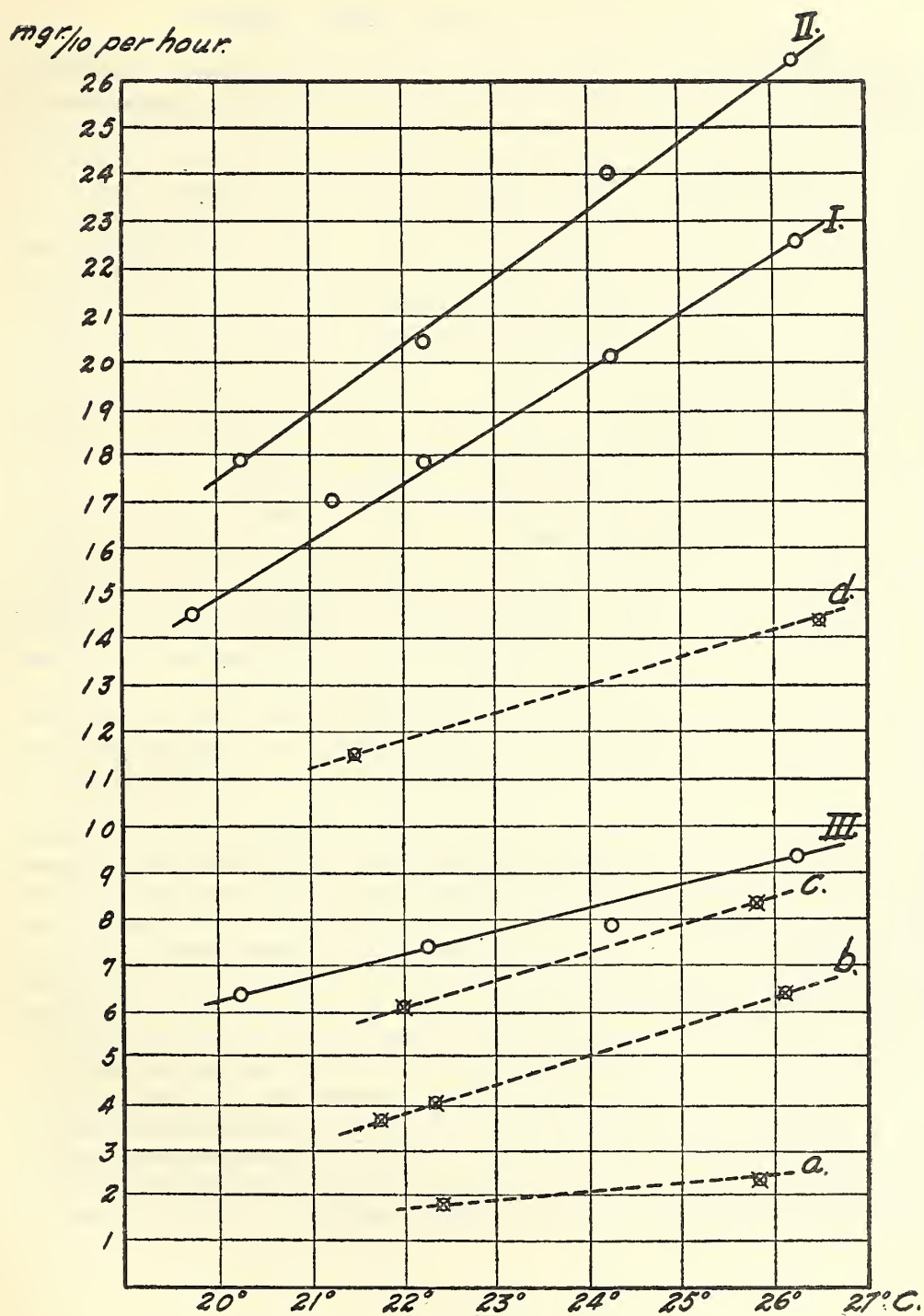
oxygen used by the shells. The shells of each oyster were at the end of the observations carefully cleaned in sea water and then used for two or three measurements of their oxygen-absorbing power at different temperatures. As these results were obtained under the same conditions as those expressed in table III, they represent a fair estimate of the oxygen absorbed by the shells during measurements with the intact oyster. There is reason, as will be shown below, to believe that oxygen removed from the water in this way is not utilized by the active tissues of the oyster. It seems reasonable, therefore, to subtract the amount (measured or computed) of oxygen utilized by the shells from that used by the whole oyster before computing the oxygen requirements per gram of dried tissue.

TABLE III.—OXYGEN USED BY OYSTERS.

NOTE.—Figures in parentheses are averages of measurements under approximately uniform conditions.

Weight, whole oyster.	Decimilligrams of oxygen used per hour.				Averages of same per hour per 100 grams.				Weight, dried oyster.	Average decimilligrams used per hour per gram of dried weight.			
	At 20° to 20.5° C.	At 22° to 22.5° C.	At 24° to 24.5° C.	At 26° to 26.5° C.	At 20° to 20.5° C.	At 22° to 22.5° C.	At 24° to 24.5° C.	At 26° to 26.5° C.		At 20° to 20.5° C.	At 22° to 22.5° C.	At 24° to 24.5° C.	At 26° to 26.5° C.
<i>Grams.</i> 47.8	10.6	12.2 14.1 (13.1)	14.2	17.1	22.2	27.4	29.7	35.7	1.15	7.92	9.74	10.40	12.90
73.5	16.6	20.0 17.5 (18.3)	23.1 18.5 (20.7)	22.0	22.6	25.0	28.2	30.0	1.66	8.20	8.61	9.43	9.56
153.0	19.4	22.4	21.4 21.7 24.5 (22.5)	25.2 25.9 (25.5)	12.7	14.6	14.7	16.6	2.36	5.98	6.78	6.56	7.15
173.0	23.5	24.5 24.7 (24.6)	29.2 30.8 (30.0)	39.0 34.3 (36.6)	13.6	14.2	17.3	21.2	3.64	3.49	4.00	4.53	6.10
Average.	17.5	19.7	21.9	25.3	17.8	20.3	23.5	25.9	.....	6.41	7.28	7.73	8.94

A graphic representation of the oxygen utilization of oysters at different temperatures is given on page 217. The ordinates represent decimilligrams of oxygen used per hour and the abscissæ are degrees Centigrade. The full lines represent measurements on intact oysters. Curve I is constructed from the averages of the oxygen utilization per hour per 100 grams in experiments on nine oysters as summarized in table II. Curve II is constructed from similar averages of experimental results on four oysters as shown in table III. Curve III is based on the same results used for curve II, but represents the averages of oxygen used per hour per gram of dried shell contents. The relationship between oxygen and temperature is apparently a simple one. The interrupted lines represent measurements on empty oyster shells showing the decimilligrams of oxygen used per hour by shells as recorded in table IV. Curves *a*, *b*, *c*, and *d* refer, respectively, to shells weighing 47.8, 73.4, 153, and 161 grams. The effect of temperature on the three larger shells seems to be fairly constant; their curves are parallel. The discrepancy in the smallest shell may be due to experimental error as so few determinations were made.



Relation of oxygen utilization in the oyster to temperature. Explanations in the text on page 216.

NONUTILIZATION OF OXYGEN BY CLOSED OYSTERS.

Since oysters can close absolutely water tight, it seemed possible that under such conditions they would take in no oxygen. The very small oxygen requirements of voluntarily closed individuals could not, however, be interpreted as proof of this because when the oyster appears to be closed it may be slightly and invisibly open. This was proved by graphic records. To insure closure throughout an observation it was necessary, therefore, to use some artificial closing device. Several clamps were tried. An ordinary surgeon's artery clamp was found to be most satisfactory. If clamps without imperfections, carefully vaselined, were used, they did not appreciably rust during the experiment and withdrew from the water only a small and constant quantity of oxygen. As control experiments the oxygen absorption of empty shells of oysters about the same size as the one observed was measured. The control shells were fastened together by a clamp duplicating the one used on the oyster. Water had some access to the interior of the empty shells through nicks in their edges. On their immersion in water all air was driven from them. In many experiments controls were deferred until the same oyster could be emptied and its shells used for control measurements.

The results of a number of determinations are given in table v. It is seen that in every case the experiment and its control are in close agreement, as the difference is within the limit of experimental error except in the case of the largest oyster used. Even these differences, however, show a larger oxygen absorption by the empty shells than by the closed intact oysters. That the slight oxygen disappearance does not represent a respiratory intake by diffusion through the shells is indicated not only by the controls but by the observation that a two hours' exposure of the clamped oyster does not cause twice the oxygen absorption observed during one hour. Thus in one experiment a clamped oyster used 1.83 decimilligrams of oxygen in one hour, but 3.01 in two hours, while another, which used 1.70 decimilligrams in one hour, required 2.80 for two hours.

The explanation of the constant slight absorption of oxygen by clamped oysters and empty shells was not positively determined, but would seem to lie in several causes. Bacteria and various marine vegetative growths on the shells were first considered as possible oxygen users. Oyster shells that had been soaked 16 hours in 80 per cent alcohol and then carefully scrubbed and dried, did, indeed, show a diminished oxygen absorbing capacity, in one case lowered from 5.25 decimilligrams per hour before the alcohol treatment to 4.68 after it, and in another, from 3.08 to 2.34. This indicates that foreign growths do not account for all the oxygen absorption, and, indeed, it was found that the cleanest and most carefully sterilized shells took oxygen from the water.

An adsorption effect of porous substances on dissolved oxygen suggested itself as another possibility. It was found that porcelain evaporating dishes about the size of oysters showed equivalent oxygen absorbing powers. Corks had the same capacity. Water containing medium sized corks lost 2.34 decimilligrams of oxygen per hour, while in a control experiment water alone lost only 0.26 decimilligram, which is within the limit of experimental error.

TABLE IV.—OXYGEN ABSORBED BY EMPTY OYSTER SHELLS.

Weight of whole oyster in grams.....	47.8	47.8	73.4	73.4	73.4	153	153	161	161
Temperature of experiment in degrees centigrade..	22.4	25.8	21.7	22.3	26.1	22.0	25.8	21.5	26.5
Oxygen absorbed per hour in mgr/10.....	1.9	2.4	3.6	4.1	6.3	6.1	8.3	11.5	14.4

TABLE V.—OXYGEN ABSORBED BY CLOSED OYSTERS.

Weight of oyster.	Temperature of experiment.	Oxygen used per hour.	Description of control experiment.
	°C.	Mgr/10.	
45 grams...	22.0	1.70	Empty shells of same oyster with artery clamp.
Control.....	22.0	1.70	
50 grams...	22.0	1.83	Do.
Control.....	22.0	1.83	
66.5 grams...	23.2	2.04	Do.
Control.....	21.0	1.92	
Control.....	23.2	2.58	Empty shells of oyster weighing 45 grams with clamp.
66.5 grams...	20.5	1.41	
Control.....	20.5	1.48	Empty shells of oyster weighing 51 grams with clamp.
128 grams...	20.5	1.79	
Control.....	20.5	1.92	Empty shells of same oyster with artery clamp.
147 grams...	20.5	1.74	
Control.....	20.5	1.62	Do.
244 grams...	20.5	1.70	
Control.....	21.0	2.34	Do.
262 grams...	20.5	3.39	
Control.....	21.0	4.68	Do.
244 grams...	27.5	3.47	
128 grams...	27.5	2.36	Control experiments not made.
66.5 grams...	27.5	2.49	
76 grams...	27.5	2.80	

RESISTANCE OF OYSTERS TO LACK OF OXYGEN.

A series of experiments was undertaken to find out the minimum oxygen supply that would maintain an oyster alive. The sea water surrounding an oyster in a vacuum desiccator was as far as possible rendered oxygen free by boiling at room temperature under diminished pressure for half an hour. It was found in two trials that sea water alone when so treated and kept twelve hours in the closed desiccator still had an oxygen content less than 0.5 of a part per million. An oyster kept under these circumstances four days showed no ill effects. Another was kept thus three days, transferred to a second desiccator of exhausted sea water, which was quickly again pumped out, and was then kept four days further in the oxygen poor medium. The shells then had some black deposits on them indicative of incipient anaerobic putrefaction. The sea water on opening the desiccator was found absolutely oxygen free. The oyster, however, seemed unimpaired, and after remaining in the aquarium some time was opened and found apparently entirely normal. As each desiccator held about 1,200 c. c. and the oxygen content of the water in each case was at the most 0.5 of a part per million, the oxygen available to the oyster might be estimated as 1.2 milligrams plus the small amount obtained during the transfer from one desiccator to the other. If we disregard the latter source because the oyster was tight closed at the time, only 1.2 milligrams of oxygen were used during seven days.

In another experiment an oyster was kept three days in the first desiccator full of pumped-out water, three days in the second, two days in the third, two days in the fourth, and two days in the fifth. By that time it was black and unable to close properly. After a few hours in the aquarium it showed disintegration, so that twelve days of life in oxygen-poor water proved fatal. Time and facilities for carrying out many of these experiments were missing, although the seven-day experiment was practically duplicated by one in which an oyster was kept in the same desiccator full of water six days with no ill effects. That the fatal effect of a twelve days' exposure was not due to insufficient renewal of the water was shown by control experiments in which several oysters were kept in the same water during fourteen days while air was bubbled through it. The oysters survived this treatment uninjured.

OXYGEN REQUIREMENTS OF CLAMS.

Measurements on clams were made by the same method used for oysters. The results of successful experiments are embodied in table VI. They show a general agreement with measurements on oysters. The amount of oxygen used by clams weighing about 60 grams is somewhat higher per 100 grams than that used by an oyster of about the same weight and observed at the same temperature. Computed per gram of dried shell contents, however, the oxygen requirements of the clam seem somewhat smaller than those of the oyster. Here, as with oysters, the amount of oxygen used is more or less proportional to increase in the temperature, though sufficient data to show a simple relationship were not obtained. In this case, also, the oxygen requirement per gram is less in the larger individual than in the smaller, again like the oyster.

TABLE VI.—OXYGEN USED BY CLAMS.

NOTE.—Figures in parentheses are averages of measurements under approximately uniform conditions.

Weight whole clam.	Decimilligrams of oxygen used per hour.			Averages of same per hour per 100 grams.			Weight dried clam.	Average mgr/10 used per hour per gram, dried weight.		
	At 20° to 21° C.	At 22° to 22.5° C.	At 24° to 24.5° C.	At 20° to 21° C.	At 22° to 22.5° C.	At 24° to 24.5° C.		At 20° to 21° C.	At 22° to 22.5° C.	At 24° to 24.5° C.
<i>Grams.</i>							<i>Grams.</i>			
7.0	1.2 3.0 (2.1)	.....	.....	29.6	.....	.....	.....	.....	.....	.....
19.5	5.19	9.7	15.1	26.7	49.7	77.4	1.32	3.93	7.35	11.4
21.0	9.2 6.7 (7.9)	.....	.....	26.9	.....	.....	.....	.....	.....	.....
28.0	8.2	.....	.....	29.3	.....	.....	.....	.....	.....	.....
57.0	11.0 12.4 (11.7)	.....	.....	20.7	.....	.....	.....	.....	.....	.....
57.5	.....	17.2	30.0	.....	30.0	52.2	3.97	.....	4.34	7.55
60.0	.....	19.1	.....	.....	31.9	.....	.....	.....	.....	.....
63.0	17.7 15.2 (16.4)	.....	.....	25.8	.....	.....	.....	.....	.....	.....

TABLE VII.—OXYGEN ABSORBED BY CLOSED QUAHOGS.

Weight of quahog in grams.....	150	150	91	91	246	246 ^a	150 ^a	150 ^b	91 ^b
Temperature in degrees centigrade.....	24.0	24.0	24.0	23.0	24.3	23.0	23.0	23.6	23.5
Oxygen per hour in mgr/10.....	.37	.25	.38	.25	.23	4.60	4.30	2.43	2.95

^a Voluntarily closed but not clamped.^b Measurements on empty shells alone.

OXYGEN ABSORPTION OF CLOSED CLAMS.

Only one experiment was made in this connection. A medium-sized clam was closed by an artery clamp over the siphon end of the shells. As a control, empty shells of an oyster of the same size similarly clamped were used. The live clam absorbed 2.68 decimilligrams of oxygen per hour at a temperature of 23.5° C., while the shell took 2.58. This indicates that the clam, like the oyster, has little or no opportunity to obtain oxygen when the shell is not open. Further observations incidentally made confirm this conclusion. A medium-sized clam which visibly failed to open throughout an experiment to determine its oxygen requirements took only 2.44 decimilligrams of oxygen from the water in an hour. Other similar results were obtained.

OXYGEN REQUIREMENTS OF QUAHOGS.

Great difficulty was experienced in measuring the oxygen utilization of quahogs, because they seldom opened for any length of time under the conditions of experimentation. As a result of this, only a few measurements that could be considered reliable were obtained. It was found necessary to place the specimen in sea water in the desiccator a long time before the experiment, usually the night before, in order to have it open at the time of observation. Handling or moving caused it to close and stay closed for some hours.

The few successful observations showed a rather low oxygen utilization. One specimen weighing 91 grams used, at 24° C., 10.1 decimilligrams of oxygen in one hour, 10.8 in another measurement, and 6.4 in a third. Another quahog, weighing 150 grams, used, at 24° C., 7.8 decimilligrams per hour, and a large one (470 grams) used 22.4 decimilligrams per hour. Many other measurements were attempted, but owing to closure soon after the beginning of observation were unreliable. The oxygen requirements in proportion to the dried weight showed a still greater discrepancy in comparison with similar computations for the oyster. The dried weights of the shell contents of the first two quahogs observed were, respectively, 2.22 grams and 3.86 grams. The oxygen used per hour and per gram of dried weight, then, was 4.10 decimilligrams for the first and 2.21 for the second. This is less than half the amount of oxygen used by oysters of comparable weight observed at the same temperature. To prop the shells open seemed hardly worth while, because the oxygen utilization under such circumstances would be abnormal on account of the resulting violent contractions of adductor muscles. It seemed best, therefore, to be content with the conclusion that under the circumstances of these experiments quahogs used only a small quantity of oxygen.

UTILIZATION OF OXYGEN BY CLOSED QUAHOGS.

Clamping these shells as in the experiments described for oysters showed that closed quahogs used no oxygen. Their very smooth shells apparently took almost no oxygen from the water. With various sizes of quahogs clamped and observed at 24° C., results were obtained as follows: 0.37, 0.25, 0.38, 0.23, and 0.25 decimilligram of oxygen per hour. The empty shells, considerably broken in the process of opening, used a distinctly larger amount of oxygen than did the closed intact animal. The small amounts of oxygen taken up under these conditions are no more than would disappear from the sea water with a clamp in it.

It was clearly shown, however, that voluntarily closed quahogs did take up appreciable quantities of oxygen. In observations where the shells were apparently quite closed, various medium and large sized specimens took up, at 24° C., 2.9, 6.1, 4.6, and 4.3 decimilligrams of oxygen per hour. It would seem, then, that when voluntarily closed they do not remain shut absolutely tight, but take in small amounts of water through an aperture too narrow to be visible to the naked eye. The results are summarized in table VII.

CONCLUSIONS.

1. Oysters of medium sizes, at temperatures between 19° and 28° C., used from 7 to 35 decimilligrams of oxygen per hour per 100 grams of entire weight. The amount varies with the temperature, so far as experiments show, according to simple relationship, so that the curve approximates a straight line. It is proportionally less for larger specimens. The oxygen utilization is, however, exceedingly variable, depending on a variety of conditions, most of which probably affect the openness of the shell.

2. Oysters when tightly closed take no oxygen from the surrounding water; at least, no more than is taken by empty shells.

3. Oysters show considerable resistance to lack of oxygen. Only exposure for more than a week to water containing very small quantities of oxygen proved fatal. This indicates that any conditions causing temporary decrease in the available oxygen are not a significant factor in oyster culture.

4. The common clam (*Mya arenaria*) shows a higher oxygen requirement than the oyster. This seems surprising, in view of the fact that clams so often exist in muds where oxygen-consuming putrefactions are going on. The oxygen requirements of clams and oysters in proportion to their dried weights are about equal.

5. Both clams and quahogs (*Venus mercenaria*) use no oxygen from the water when tightly closed, but the quahog takes up oxygen while slightly and invisibly open.

6. The oxygen requirements of the quahog are, under the conditions of these experiments, conspicuously low.

THE ANTHOZOA OF THE WOODS HOLE REGION



By Charles W. Hargitt

Professor of Zoology, Syracuse University

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INTRODUCTORY.

The present report aims to present in convenient form a synoptic account of the Anthozoa (Actinozoa) of the region, adapted alike to the needs of the general worker in systematic zoology and those desiring in brief compass a modern survey of the habits, characteristics, and local distribution of the group.

The material forming the basis of the report has been collected for the most part by the writer at various times during the past five years, though some of the specimens of deep-water habitat were collected by the *Fish Hawk* during dredging expeditions at various times within the past 10 years. A record of these latter collections will be noted in connection with the several species concerned.

It is again my pleasure to acknowledge the assistance of Mr. Vinal N. Edwards in many ways. My thanks are also due to Commissioner George M. Bowers and to Dr. F. B. Sumner, director of the laboratory, for many courtesies.

GENERAL ACCOUNT.

Anthozoa are marine animals of various range of distribution, habit, size, etc., and variously known as actinians, sea anemones, polyps, etc. In general they are more or less sedentary, i. e., attached to some permanent support, such as rocks, piles, etc., or in some cases (Alcyonaria) rooted in the sandy bottoms where they thrive, or in still other cases (corals) forming a calcareous skeleton, which in the subtropical species gives rise to complex reef masses. Not a few of the actinians have a measure of locomotor power and creep, snail-like, over the supporting base to which they are attached. And again still others are given to a commensal mode of life, forming the well-known partnerships with hermit crabs or other creatures of similar habit. Further notice of these peculiarities will be given in connection with the species which exhibit the trait.

Anthozoa, in common with other classes of cœlenterates, may live a wholly solitary and independent life, as in most actinians, or may form highly complex colonies, as in most corals and Alcyonaria. In the case of colonial species the polyps are usually

united in more or less compact masses, the whole colony being brought into communal relations by means of a common body substance, the cœnenchyme, through which a system of gastric canals ramifies in various degrees, and thus directly or indirectly brings the various individuals into communication, both for nutritive and for protective purposes. It is most interesting to observe the sensory continuity which prevails in one of these colonies. Any irritation which disturbs one polyp is promptly conveyed to every individual of the colony, a sensory wave passing over the community not unlike that produced by the wind upon a field of grain or tall grass.

MORPHOLOGY.

In form and structure Anthozoa have many features of very considerable interest, not only to the critical student of morphology but to the casual observer or student of natural history. In form there is exhibited a wide range, from the simple polyp, of minute size and of structure hardly more complex than that of a hydrozoan, to the complexity and mass of immense communal aggregates of reef corals and sea plumes and gigantic anemones more than a foot in diameter.

In fundamentals of structure there is of course a more or less intimate homology running throughout the entire class, though with considerable ordinal peculiarities, and even generic and specific features more or less unique. The general form of the individual polyp, whether actinian or alcyonarian, is cylindrical or barrel-shaped, with a hollow gastric interior. Usually the height is considerably greater than the diameter, but owing to the highly contractile powers of the organisms these proportions vary greatly under various conditions of contraction. The body is terminated by a basal portion usually known as the foot, or pedal disk, and by an upper terminal portion, the oral disk, or peristome. The body proper is usually designated as the column. In sedentary species the pedal disk forms an organ of attachment, or in those having motile power constitutes the chief organ of locomotion. This feature is rather peculiar to the free-living species, though it may be absent in such tube-dwelling forms as *Cerianthus*.

The oral disk is characterized by the presence of a distinct mouth, which is usually of oval shape, especially in actinians, and with its edges, or lips, more or less folded or corrugated. The mouth communicates with the gastric cavity or enteron through an œsophagus, the inner end of which opens abruptly into the gastric cavity.

A series of radially arranged septa, the mesenteries, connect the inner walls of the œsophagus with those of the body, thereby forming a regular series of alternating septa and pockets, the latter ending blindly at the oral disk above, except as they may communicate with the bases of hollow tentacles, but opening freely below into the enteron. The margins of the mesenteries below their œsophageal connections are often more or less thickened, and bear filaments which are characteristic of Anthozoa. They are composed of entoderm, and are richly supplied with gland and nettling organs. In many actinians these latter organs are threadlike, highly contractile structures known as acontia, which are loaded with specialized nettling cells, and may be

thrust out of special pores, cinclides, or through improvised openings in the tissues of the body wall.

The marginal portion of the oral disk bears the tentacles, which are usually hollow outgrowths from this part of the body. They vary greatly in size and number in different species and genera. In Cerianthidæ they form two distinct sets, the circumoral, surrounding the mouth, and the marginal, corresponding to those of other orders. The latter are often designated as primary or principal tentacles; the former as accessory or circumoral.

As indicated above, the general form of the body as a whole is more or less cylindrical. Peculiarities of distinction will be considered in connection with those species exhibiting them. This will also be the case in reference to particular features of oral or pedal disks. In many of the orders some form of skeleton, calcareous or horny, is present. This is particularly the case with most corals and alcyonarians. On the other hand, most or all actinians are entirely devoid of anything of the sort.

Another feature of some significance is the habit of certain actinians to expand and inflate the pedal disk and thus convert it into a float by means of which they are able to migrate under the influence of currents, much as do certain other pelagic coelenterates (*Vesalia*). This has been observed in several local species, and it seems not unlikely that it may be of more general occurrence than might be supposed. Among those which exhibit the phenomenon may be mentioned *Sagartia luciae*, *S. leucolena*, and *Anemonia sargassensis*. It should be stated, however, that this has been noted only in specimens in the aquarium; but its occurrence under these conditions with more or less frequency would strongly suggest its occurrence in nature under certain circumstances.

COLORATION.

In comparatively few classes of animals are there richer or more varied exhibitions of color than among Anthozoa. This is particularly striking in the tropical or subtropical species. To those who may have had the exquisite pleasure of looking upon the splendid display of colors associated with coral reefs no emphasis will be needed on this point; and to others an adequate verbal description would seem highly exaggerated. The profusion of coloration and the plantlike features of many of these coelenterates are doubtless the occasion of such names as anemones, anthozoa, zoophytes, etc., by which many of them are known even to this day.

Into the problem of the origin or significance of colors in these lower classes no attempt will be made to enter seriously. Something of this has been done by the writer in an earlier paper (1904) and to a less extent in a report on the Medusæ of Woods Hole (1905). However, there are some points of particular phases of color involved in Anthozoa which call for notice. In the first place, it is interesting and significant that among these creatures color is due to distinctly different factors. For example, Duerden (1905) has shown that among many corals the dominant color is due to the presence of commensal algæ, *Zooxanthellæ*, which thrive in the entodermal tissues of the polyps.

In such cases the problem of color is transferred from the animal to the plant, which relieves the present discussion of any particular consideration of the matter. It may suffice, therefore, to say that in such cases color is only of secondary or incidental biological significance, and is meaningless in relation to any problem of adaptation or protection. In the words of Duerden, "The rich profusion and beauty of color in coral polyps certainly seems to have no protective or warning significance" (op. cit., p. 16).

But even in organisms in which color is constitutional there is little or no relation to environmental influences. For example, many actinians and alcyonarians living under identical conditions have very different color features; and, on the other hand, species of widely differing habitats and diverse environments exhibit closely similar aspects of coloration. Furthermore, a species which shows remarkable color variations in a given habitat will often show the same variations through its entire range of distribution. As an example of this may be cited the well-known case of the common *Metridium marginatum*. The world-wide distribution of this species (assuming with McMurich its identity with *M. dianthus*), and the very similar aspects of coloration, illustrates the point under consideration, showing that conditions of environment or habitat have little to do with the character or variation of colors, at least so far as this species may have any significance.

The influence of conditions of nutrition, as already shown by me in former papers (op. cit.), act in similar manner on Anthozoa. Actinians kept in the aquarium very soon show color changes indicative of lowered states of vitality, unless pains be taken to obtain approximately natural conditions. In the celebrated Naples aquarium this has been more successfully done than I have seen elsewhere. Here certain species of actinians have thrived for years with little loss of vitality or change of coloration.

PHOSPHORESCENCE.

Among the many various and complex phenomena of life few are more unique or obscure than that of phosphorescence, or vital luminosity, the former name being more or less a misnomer, since except in appearance there is little or nothing in common between the phenomena to which it was originally applied, and those associated with living things. However, the term has become so generally associated with all sorts of luminous phenomena of similar appearance, and devoid of appreciable heat, that its use is likely to continue; and if care be taken to discriminate no serious confusion is likely to arise.

The occurrence of phosphorescence in many species, and in a wide range throughout the entire class, makes some reference to the subject more or less incumbent. While probably much more general in tropical and subtropical waters it is yet fairly common elsewhere, being well known throughout the region concerned in this report.

Much speculation has been aroused concerning its use or significance, and various and conflicting theories projected. No attempt will be made here to review the subject historically, nor to cite the various differences of opinion which have grown up.

Among the older students of cœlenterates Johnson and Forbes made observations and experiments in connection with the subject, and in turn cite similar observations made by Ehrenberg, Spallanzani, and others, showing no less interest than has been common in later times.

Macartney proved by experiments that the phenomenon might be aroused by a wide variety of stimuli, such as temperature, mechanical disturbance, chemical agents (as alcohol), electricity, etc. Forbes was able to confirm certain of these results, and also proved that in the phenomenon there was no evidence of electrical discharge, and further that no heat was evolved in connection with the emission of light.

Allman also studied the subject in connection with hydroids. He found the phenomenon exhibited by various calyptoblastic hydroids, but not in any known gymnoblastea. Like other observers, he found that various physical and chemical stimuli were needed to evoke displays of light. He was not able to find any phosphorescent secretion in the hydroids, such as had been found in connection with insects and other phosphorescent organisms.

Among Anthozoa its occurrence has been best known in groups of alcyonaria, especially in species of *Pennatula*, *Gorgonia*, etc., but not unknown in such solitary forms as the actinians. In the latter it has been observed chiefly in the slimy secretion of the ectoderm.

Reference has already been made to the conflicting theories as to the significance of phosphorescence. A few words must suffice on this point. It was suggested by both Carpenter and Thomson that it might have some importance as a source of abyssal light, thus affording some means by which the inhabitants of the darkness of great depths might be aided in finding food, evading enemies, etc. But, on the other hand, Mosely has pointed out the inadequacy of such a view. Many facts seem utterly in conflict with the theory. For example, the light of organisms from these depths has been found to be more or less monochromatic, or of only two or three colors. This would suggest that other colors would be invisible under such light, hence incompatible with the theory. He concludes that colors of deep-sea forms are probably only incidental, or features persisting from earlier conditions when the creatures were inhabitants of shallow waters. And on this and similar grounds he adduces a strong argument as to the comparatively recent migration of many of the abyssal forms into their present habitat.

Verrill has suggested that phosphorescence might serve as a warning to predaceous fishes that luminous organisms were provided with weapons of defense which it were well to evade. A. Agassiz has pertinently suggested that the well-known cases of *Physalia*, *Cyanea*, etc., and their commensals, and the habits of many fishes of feeding constantly in the coral and alcyonarian forests, all went to prove that "they are not in dread of lasso-cells." Among the most brilliantly phosphorescent of our local fauna are ctenophores. But it is well known that these are fed upon by a number of fishes. It may be safely assumed, therefore, that Verrill's suggestion is utterly without significance as an explanation.

More recently Nutting has suggested the ingenious view that phosphorescence may serve as a lure, attracting copepods and various larvæ within reach of the luminous organism. "The process would be analogous, perhaps, to what is known as the effect of alluring coloration among insects and birds. The phosphorescence would thus be of direct utility to the fixed cœlenterates in securing food." Unfortunately, there is no more evidence in support of this than in that of Prof. Verrill. And on the other hand, there is much which goes to show that such a view is directly in conflict with too large a mass of facts to render it at all probable. Such are the facts of phosphorescence in littoral forms, and in free-swimming and surface forms, whose modes of taking prey render it highly improbable that they have any need of such an aid. Phosphorescence is not solely a property of deep-sea life nor of nocturnal feeders. The writer regards it as associated with processes of metabolism; and while not beyond the realm of utility to the organism it is not directly so. Theories dealing with the subject have been propounded on the assumption that every vital feature and phenomenon must be brought into alignment with natural selection. It is to be hoped that we are emerging from the shadow of that assumption.

REPRODUCTION.

Generation in this class, as in others of the phylum, is both sexual and asexual, though without the more or less rhythmic alternation of generations so characteristic of the Hydrozoa. The sexual products are borne on certain of the mesenteries, and when ripe are usually extruded through the mouth. In some species, however, development may take place within the mesenterial chambers, and the young later discharged in a fully formed condition. The sexes are usually distinct, as in most Hydrozoa, but may be united in a single individual in certain species. That is, Anthozoa may be either dioecious or monœcious—unisexual or bisexual. Duerden has shown (1904), in the case of certain corals, that the bisexual or hermaphrodite condition may prevail, a given individual producing both ova and sperms, though not at the same time. That is, the genital products mature at somewhat different intervals, the organism being protogynous, maturing the ova first; or it may be protandrous, maturing the sperms first.

Asexual propagation is of general occurrence and of great importance. It is chiefly by the process of budding; though fission is not unknown among actinians, a given specimen dividing longitudinally, much as in *Vorticella*. Parker (1897, Bulletin of Museum of Comparative Zoology, p. 43) has described this process in *Metridium marginatum*, and Torrey has shown the same in the case of *M. fimbriatum* (Proceedings California Academy of Sciences, vol. 1, p. 345, 1898). The writer has observed the entire process take place in *Sagartia lucia*, a small but extremely interesting anemone of our coast. In this species fission is apparently a common feature of reproduction. In text figure 1 is shown a sketch of a *Metridium* in process of fission. Such specimens are not particularly rare. Still another mode of asexual reproduction is more or less familiar, namely, that known as fragmentation. It consists of the formation of numerous minute individuals by a sort of indefinite budding from the margins of the pedal disk. This process seems

to be rather common in *Metridium marginatum*, as I have found many cases occurring, both in the aquarium and in a state of nature. Torrey (op. cit.), has suggested that it may be due to the unfavorable conditions of the aquarium, but its occurrence in natural conditions as just cited would preclude this as a cause.

DISTRIBUTION.

Anthozoa are of wide distribution, both in time (geological) and in space (geographical), and also in bathymetrical range. Of the first, or geological, it is not within the scope of the present paper to take notice. Of geographical range it may suffice to say that, like the former, a general consideration of the problem is not designed in the present review. Many conditions are involved in the matter of distribution, among which temperature plays an important part. This is particularly the case with alcyonaria, which are predominantly tropical or subtropical organisms. The same may also be said of the coral group, or Zoanthariæ.

In bathymetrical range there is great variation among the several groups. Many of each have been dredged from great depths, but by far the larger number have their habitat in shallower seas and along shore lines. In certain cases a given species may find itself equally at home in depths of from 50 to 1,500 fathoms. *Bathyactis* is recorded as being found in depths of from 50 to 3,000 fathoms.

ECONOMIC RELATIONS.

In common with cœlenterates in general, the economic relations of Anthozoa are chiefly incidental and indirect. A few fishes are known to feed on corals, a few on hydroids, perhaps still fewer on alcyonarians or others. So far as I am aware, actinians are usually immune from predatory attacks. Furthermore, certain actinians may serve as hiding places for small fishes, which have established commensal relations with them. On the other hand, not a few actinians feed upon fishes more or less freely. The commensal relations of actinians and hermit crabs are well known.

Indirectly corals have played a very important part in the contour of islands and continents from Paleozoic to recent times. And at present in subtropical regions these organisms are constantly concerned in the extension of certain coast lines by the formations of reefs along its margins. Thus, may be reclaimed something of the areas constantly being lost through erosion and transportation of continental débris into the seas; but, on the other hand, growth of these organisms in harbors and roadways of steamships often involve obstructions and dangers hard to overcome.

SYSTEMATIC ACCOUNT.

In common with that of other classes of cœlenterates, existing conditions of taxonomy of Anthozoa are not highly satisfactory. Several attempts at revision have been made within comparatively recent times, but much yet remains to be done before an orderly and adequate system of classification will be established. Among those who

have contributed materially to this end may be mentioned the following: Hertwig, R. and O. (1879); Hertwig, R. (1882); Andre, A. (1884); McMurrich, J. P. (1894); Van Beneden (1897); Carlgren (1900). These works are devoted almost exclusively to the Actinozoa. Similar work upon the Alcyonaria has been done by May (1899), Kukenthal (1905), and Studer.

While it is no part of the purpose of this report to enter into the matter of taxonomy in any detail, it may not be amiss to include brief synoptic tables indicative of opinion as to this phase of our subject, at least, as relates to Actiniaria. A valuable review of the history of taxonomic development along this line may be found in the report of McMurrich on the Actiniæ of the *Albatross* Expedition (Proceedings, U. S. National Museum, vol. XVI, 1893, p. 119-135). Brief historical references are also made by Hertwig (*Challenger* Report, vol. VI, p. 16-18) to this phase of the general subject, though with no attempt to trace the development of taxonomic systems.

Concerning the systems proposed by Van Beneden (1897) and Carlgren (1900), it is hardly within the scope of this paper to undertake an adequate review. Both are noteworthy contributions and will command the attention of specialists everywhere. They involve, however, considerable of embryological and histological details and methods, and are hence somewhat too technical for use in the present instance.

Under almost all modern systems of classification the musculature of the body has constituted one of the most important taxonomic characters. It becomes necessary, therefore, to devote some further attention to this feature. As to their relations, the muscles may be said to be ectodermal, entodermal, or mesodermal, as they are associated with these several tissues. The musculature is disposed chiefly in two positions, namely, (1) as longitudinal fibers distributed to the walls of the column; (2) as circular bands distributed variously over the body. Of the latter there is usually a special development in the oral region known as the sphincter. This acts as an organ for closing the mouth, much as one might close the opening of a bag by a draw string.

R. Hertwig has emphasized the importance of various aspects of the musculature as taxonomic features and says:

The nature of the sphincter varies greatly. We talk of a diffuse sphincter when it arises from repeated pleatings of the muscular lamella; in that case because it is not sharply defined at the upper and lower margins, it does not strike the eye in looking at the surface, and is shown in transverse sections only by the local thickening of the wall in whose substance it is completely embedded. A circumscribed sphincter is formed when the pleated muscular mass projects above the inner surface of the wall, with which it is connected only by a narrow band, so that an annular swelling arises which is easily observed both in looking at the surface and in transverse section.

Finally, in the mesodermal sphincter, the muscles have left their original position in the epithelium and are completely hidden in the supporting substance, which consequently increases doubly or trebly in thickness. The complete absence of the sphincter is comparatively rare. I have only observed it in a few species, almost invariably animals which are not capable of contracting the upper margin of the wall over the oral disk. This is, however, also the case in animals with a weak sphincter, such as the Anthedæ. On the other hand, the existence of a strong circular muscle can often be inferred with tolerable certainty from a high degree of contraction. The capacity for concealing the oral disk plays an important part in the systematic division of the Actiniaria; this is generally most inappropriately expressed by the term "retractile tentacles." It would be decidedly more rational to make the ana-

tomical reason, and not the physiological appearance, of systematic value. We shall therefore talk of Actiniaria without sphincter, and Actiniaria with weak and with strong sphincter, and further distinguish in the latter case whether the muscle is entodermal or mesodermal.

The systematic value of the circular muscle does not end here, as it furnishes a character not to be undervalued for determining the species. * * * I lay stress upon this point, as the circular muscle can be examined in the preserved animals even when their state of preservation is not very favorable, and because, moreover, a small piece of the wall, which can be cut away without essential damage to the whole animal, is sufficient for such an investigation. (Challenger Report, vol. VI, p. 6-8.)

Class ANTHOZOA.

The class Anthozoa, as limited in this synopsis, comprises some two well-marked subclasses, namely, the Alcyonaria and the Zoantharia. A third subclass, the Rugosa, includes only fossil forms, which makes it undesirable to cumber the present report with any account of it.

Each of the two subclasses above named comprises in turn three rather well differentiated orders, all, with a single exception to be named later, having representatives among the local species. The following synopsis of orders may serve as a formal introduction to the taxonomy of the Anthozoa.

ALCYONARIA.

The order Alcyonaria includes those members of the class Anthozoa which are characterized by the presence of eight pinnate tentacles and a corresponding number of mesenteries. All are of marine habit, and most are colonial, forming more or less complex clusters of polyps united to a common stock, and with or without definite skeletal structures. In most cases, however, there is a skeleton composed of calcareous spicules of various form and color giving to the colonies the characteristic spiny surface of many gorgonians and similar forms.

The distribution of these spicules may be somewhat general throughout the tissues of the body, or they may be aggregated into a dense axis as in the so-called black and red corals and in the familiar sea fans, etc.

ORDERS OF ALCYONARIA.

I. *ALCYONACEA*.—Colonial, with a well developed anastomosing canal system. Stem usually devoid of axial skeleton, but the coenenchyma bearing numerous separate spicules.

II. *PENNATULACEA*.—Colonial, with a stem loosely attached in mud or sand, and capable of some degree of locomotion; an axial skeleton extends through the stem in most cases, though lacking in not a few. A specialized portion of the stem, the rachis, bears the polyps either as sessile individuals, or on numerous pinnæ which branch from the rachis, as in the familiar sea pens.

III. *GORGONACEA*.—Colonial, firmly attached by root-like bases or holdfasts. Stem and branches with definite axial skeleton of calcareous or horny character, overlaid by a cortical coenenchyma from which the polyps arise.

ZOANTHARIA (*Hexactinia*).

Polyps and polyp colonies characterized by simple or unbranched tentacles in one or more cycles about the mouth. Paired mesenteries usually in some multiple of six, though exceptions to this are more numerous than formerly supposed.

ORDERS OF ZOANTHARIA.

I. *ACTINIARIA*.—Polyps solitary, or rarely colonial, devoid of any skeletal structures, and usually adherent by a suctorial or adhesive base, the pedal disk, though capable of more or less locomotion. Mesenteries in most cases paired and in multiples of six.

II. *MADREPORARIA*.—Polyps colonial, or rarely solitary, and with a dense calcareous skeleton, forming, in most cases, a complex corallum.

III. ANTIPATHARIA.—Colonial zoantharia, usually with a hollow, branching skeleton of horny nature. So far as known, no representatives of this order occur in the region, which obviates the necessity for further account of it in this report.

SYNOPSIS OF TRIBES OF ACTINIARIA.

EDWARDSIAE R. Hertwig, 1882.

Noncolonial Actiniaria with eight mesenteries, two pairs of which are directives; others unpaired, and their longitudinal muscles face the same direction; all mesenteries gonad bearing. Tentacles simple, few in number, usually more numerous than the mesenteries, varying from 12 to 36. Column more or less linear and cylindrical, often fluted along the lines of attached mesenteries.

ZOANTHEAE R. Hertwig, 1882.

Colonial Actiniaria, with numerous mesenteries of two sorts, namely, small, incomplete, and devoid of gonads; large, complete, and gonad bearing. A single œsophageal groove. Outer surface of body usually incrustated with a coating of sand or other foreign particles. Tentacles simple.

CERIANTHEAE R. Hertwig, 1882.

Actiniaria with numerous, unpaired mesenteries, except a single pair of directives, which are very short and attached to the deep œsophageal groove. On either side of these will be found the much longer perfect mesenteries, which increase in size in regular order to the opposite (dorsal) side. Tentacles numerous and in two series—an outer principal and an inner accessory series—the circumoral tentacles. Body elongate, usually inclosed in a slimy flexible tube. Aboral end of body rounded and provided with a terminal pore.

HEXACTINIAE R. Hertwig, 1882.

Actiniaria with six or more pairs of primary mesenteries. Other cycles arise in pairs, some of which may become perfect, others incomplete. The primary mesenteries are provided with retractor muscle fibers on their inner faces i. e., the muscles of each pair facing the intramesenterial space. There are usually two œsophageal grooves, with directive mesenteries, whose muscles face outward, or opposite the aspect of the other pairs. Body more or less smooth, often with longitudinal furrows, and in certain cases with wartlike nodular processes, verucæ. Tentacles usually numerous and of various characters.

The above tribal characteristics have been variously compiled from those given by Hertwig, McMurich, Haddon, Duerden, and Gosse, and to a less extent from Andres, Verrill, and others.

FAMILIES OF HEXACTINIAE.

ILYANTHIDÆ Gosse (in part), 1858.

Body usually elongate, cylindrical, aboral end rounded and with somewhat constricted, bulblike physa, but devoid of definite pedal disk. Tentacles simple and relatively few in number, or in some cases numerous; sphincter weak.

There is considerable uncertainty as to the constitution of this family, some authorities even excluding it altogether. Gosse, who established it, included under it the Edwardsiæ as well as the Ceriantheæ. Hertwig considers the family as intermediate between the Edwardsiæ and true Hexactiniæ, and so ranks them in his system. (Op. cit., p. 92.)

ANTHEIDÆ Gosse (in part), 1858.

Hexactiniæ with well-developed pedal disk, often capable of expansion and inflation as a pneumatophore. (Cf. Gosse, *Actinologia Britannica*, p. 149.) Column generally smooth, sometimes with verucæ; tentacles long, very flexible, and disposed chiefly about the margin of the disk; mesenteries numerous; sphincter muscle very weak, rendering difficult any considerable contraction of disk or tentacles.

SAGARTIIDÆ Gosse, 1858.

Body with strong oral sphincter and numerous highly contractile tentacles. Mesenteries of two sorts; principal series in six pairs attached to œsophagus, and devoid of gonads; second series incomplete, and bearing gonads in breeding season. Acontia present and protrusible through cinclides or directly through the tissues.

BOLOCERIDÆ McMurrich, 1893.

Sphincter more or less diffuse and weak; mesenteries devoid of acontia; pedal disk well developed; tentacles stout, nonretractile, strongly constricted at base, hence often deciduous.

BUNODIDÆ Gosse, 1858.

Sphincter entodermal, "body usually studded with numerous tubercles, which are disposed in longitudinal rows, and may serve as suckers by means of which they have the faculty of adhering with force to foreign bodies." (Gosse.) Mesenteries often numerous and perfect but devoid of acontia.

PARACTIDÆ Hertwig, 1882.

Sphincter mesogleal, strong; body usually devoid of tuberculation, but with numerous longitudinal flutings; mesenteries numerous and perfect; no acontia.

TEALIIDÆ Hertwig, 1882.

"Hexactinia with numerous perfect mesenteries; sphincter strong, entodermal, projecting as a thick swelling into gastric cavity."

"The most important feature of the family is, I consider, the extremely characteristic circular muscle, which can be recognized with the naked eye, as a thick swelling on the inner side of the wall. In transverse section it shows a circular or oval figure, fastened on one side to the wall; it is formed by the extremely strong pleating of the entodermal circular muscle layer. The large number of perfect septa is also important; on the other hand, I have entirely disregarded the nature of the surface of the body, so that forms both with smooth and warty wall may find their place in the family." (Hertwig, *op. cit.*, p. 35.)

DIAGNOSTIC SYNOPSIS OF FAMILIES OF HEXACTINIDÆ (modified from Hertwig).^a

A. Tentacles forming simple wreath.

a. Digitate.

b. Pedal disk absent.

c. Siphonoglyphs and sphincter obscure { Without conchula ILYANTHIDÆ.
 { With conchula SIPHONACTINIDÆ.

bb. Pedal disk present.

d. Acontia present, sphincter mesodermal, cuticular covering { Absent SAGARTIIDÆ.
 { Present PHELLIIDÆ.

dd. Acontia absent, sphincter { Absent ANTHEOMORPHIDÆ.
 { Present { Weak ACTINIIDÆ.
 { Strong entodermal BUNODIDÆ.
 { Strong mesodermal PARACTIDÆ.
 { Mesodermal, transverse axis
 { elongated AMPHIANTHIDÆ.

aa. Tentacles abnormal in shape.

e. Clavate, knobbed HETERACTIDÆ.

ee. Replaced by stomidia LIPONEMIDÆ.

eee. Branching or bushy { SARCOPHANTHIDÆ.
 { THALASSIANTHIDÆ.

B. Tentacles form double or multiple wreaths. CORALLIMORPHIDÆ.

^a Cf. Challenger Report, vol. xxvi, pt. 73, p. 7.

DIAGNOSTIC SYNOPSIS OF FAMILIES OF HEXACTINIAE (adapted from McMurrich).^a

A. Tentacles in cyles—Actininae.

a. Column simple.

b. Tentacles cylindrical, smooth.

c. Sphincter absent or weak { Mesenteries not numerous HALCAMPIDÆ.
 { Mesenteries numerous ANTHEIDÆ.

cc. Sphincter entodermal, tentacles deciduous BOLOCERIDÆ.

ccc. Sphincter mesodermal { Acontia absent PARACTIDÆ.
 { Acontia present SAGARTIDÆ.

cccc. Sphincter entodermal, circumscribed { Acrorhagi wartlike BUNODIDÆ.
 { Acrorhagi foliate PHYLLACTIDÆ.

bb. Tentacles warty or branched { Simple HETERACTIDÆ.
 { Compound THALASSIANTHIDÆ.

bbb. Tentacles reduced to stomidia { POLYOPIDÆ.
 { SICYONIDÆ.

aa. Column in upper part with branched or globular processes DENDROMELIDÆ.

B. Tentacles radially arranged—Stychodaclylinidæ.

a. Tentacles of one form { Few, capitate CORALLIMORPHIDÆ.
 { Numerous, cylindrical DISCOSOMIDÆ.
 { Nodulated AURELIANIDÆ.

aa. Tentacles of two forms { Marginal cylindrical, disk tentacles wartlike, branched
 { or foliate RHODACTIDÆ.
 { Marginal pinnate, disk tentacles wartlike PHYMANTHIDÆ.

aaa. Tentacles of various forms, not cylindrical CRIPTODENDRIDÆ.

METRIDIDIUM Oken, 1815.

Metridium dianthus (Ellis), Oken. [Text fig. 1.]

Actinia dianthus Ellis, Phil. Trans., vol. 57, 1767.

Metridium dianthus Oken, Lehrb. der Naturgesch., 1815.

Actinia marginata Lesueur, Jour. Nat. Sci., Phil., vol. 1, p. 172, 1817.

Metridium marginatum Milne-Edwards, Hist. Nat. des Cor., vol. 1, p. 254, 1857.

Actinia marginata L. Agassiz, Cont. Nat. Hist. U. S., vol. III, 1860.

Actinoloba dianthus Gosse, Brit. Sea Anem., p. 12, 1860.

Metridium fimbriatum Verrill, Mem. Boston Soc. Nat. His., vol. 1, 1864.

marginatum Verrill, Inv. An. Vineyard Sound, p. 444, 1874.

dianthus McMurrich, Ann. N. Y. Acad. Sci., vol. XIV, 1901, p. 3. Torrey, Proc. Wash. Acad. Sci., vol. IV, 1902.

(For full details of synonymy, see Andres, 1883.)

This beautiful actinian, often designated as the "fringed sea anemone," is altogether the most common and at the same time the most conspicuous of our actinian fauna. It abounds almost everywhere from New York to Nova Scotia, from tide pools to a depth of 75 fathoms and beyond, and is one of the largest anemones of the region.

It is a remarkably variable species. This pertains to almost every aspect of the creature—size, color, habitat, structure, mode of propagation, etc. In distribution it seems to be almost cosmopolitan, being found upon both the eastern and western coasts of America, and variously over the European coasts.^b It may be doubted whether another of its relatives has a range of distribution at all comparable.

^a Cf. Proceedings U. S. National Museum, vol. XVI, p. 134.

^b In identifying the local species with *M. dianthus* of Oken, I am but following several well-known authorities, especially McMurrich, vide supra.

It may not be out of place to briefly glance at certain features of variation more or less common. In color it varies from yellowish brown, which is the more common, to orange, pink, white, or various combinations of these, in stripes, mottlings, etc. McMurrich has pointed out an apparent tendency in the coloration to assume some three types, brown, orange or salmon, and white, and has suggested a correlation as to age, modes of reproduction, etc.

Parker (1897) has also proposed similar suggestions as to this and other aspects of variation.

Duerden, whose work on Anthozoa is well known, has in a recent paper suggested the influence of light as a factor affecting color varieties.

In a still more recent paper Torrey (1902) has undertaken to ascertain more certainly the factors concerned in this and other aspects of variation, especially as it relates to this species along the Pacific coast. He concludes that as yet it is impossible to ascribe it to any definite known cause.

Body cylindrical, smooth, capable of a high degree of contractility; disk well defined, with distinct marginal lobes which are abundantly supplied with short, pointed tentacles.^a In full expansion this actinian is a most exquisite creature, beautiful and plant like, and meriting the title "the fringed anemone," often applied to it. The disk is smooth and more or less concave. Mouth rather prominent, with corrugated, or tuberculate-lips, and with well-marked œsophageal grooves, often with but one, and more rarely with three or several. Parker has directed particular attention to this feature of variation, as has also Torrey. (Cf. op. cit., supra.)

As an explanation of this feature the suggestion has been made that it may have its origin in the process of fission, often involved in asexual reproduction. Torrey doubts the validity of this view. In text figure 1 is shown a careful drawing of one of these twin anemones in process of fission.

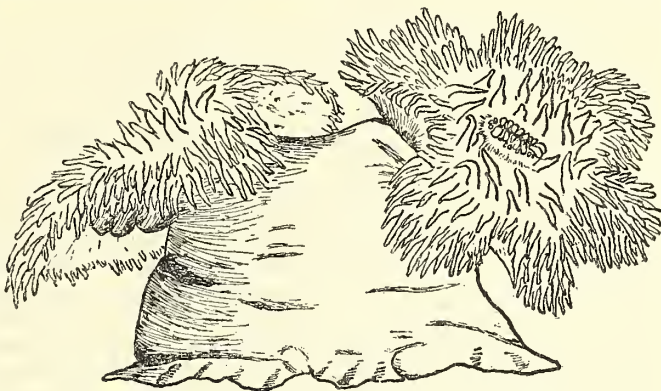


FIG. 1.—*Metridium dianthus*. Specimen in process of fission.

A brief reference has been made in an earlier connection to this aspect of reproduction. In this connection may also be noted the process known as fragmentation, the origination of small individuals by a sort of budding process of portions of the margin of the pedal disk. This is frequently observed in specimens in the aquarium, but I have found it occurring also in specimens taken from piles about the docks, making it quite certain that it is not due to any unusual or abnormal conditions.

The pedal disk is strongly adhesive and capable of being used as an organ of locomotion, the creature creeping with a slow, snail-like movement from place to place. The mesenteries are abundantly supplied with acontia, which are protruded in profusion from both the mouth and through cinclides when a specimen is irritated. The sphincter is mesoglear and strongly developed, enabling the creature to contract in a most remarkable degree. Mesenteries very numerous in adult specimens and more or less variable as to number and arrangement.

Distribution and habitat: As has already been pointed out, the range of this species is very wide. It may be doubted whether any other known species has quite so remarkable a distribution. It is found abundantly throughout the region of Woods Hole and along the entire New England coast. Its habitat is in keeping with the range of distribution. It abounds in tide pools, upon rocks, piles, shells, algæ, etc.

^a Tentacles of inner or oral series larger, attenuate in form, and often marked by transverse bars or rings of opaque whitish color.

HALCAMP A Gosse, 1858.

Halcampa farinacea (Verrill), Andres.

Edwardsia farinacea Verrill, Am. Jour. Sci., vol. 42, 1866, p. 118; Inv. An. Vineyard Sound, 1873, p. 510, 739.

Halcampa farinacea Andres, Fauna u. Flora Golfes Neapel, bd. ix. Parker, Am. Nat., vol. XXXIV, 1900, p. 750.

This species has been reported by Verrill as occurring off Gay Head in 19 fathoms. Its chief range, however, seems to be north of Cape Cod. The present writer has not taken it in the Woods Hole region. The following brief description is chiefly compiled from that of Verrill (vide supra): "It is a cylindrical species, about an inch long, and from 0.10 to 0.12 inch in diameter, remarkable for having only 12 tentacles, which are equal, unusually short, thick, and blunt." Tentacles rather translucent, with transverse bars on inner side of brownish bands or spots. Alternating with these are bars or spots yellowish or white. Disk pale yellow, varied with small brown spots, mostly forming radial rows from mouth to tentacles.

Habitat: Found only on muddy bottoms.

EPIZOANTHUS Gray, 1867.

Epizoanthus americanus Verrill.

Zoanthus parasiticus Verrill, Mem. Boston Soc. Nat. Hist., vol. 1, 1864, p. 34.

Epizoanthus papillosus Gray, Proc. Zool. Soc. Lond., 1867, p. 237.

americanus Verrill, Am. Jour. Sci., 2d ser., 1871, p. 361; Inv. An. Vineyard Sd., 1873, p. 446, 510; Bull. Mus. Comp. Zool., vol. xi, 1883, p. 60.

paguriphilus Verrill, Am. Jour. Sci., 1882, p. 137; Bull. Mus. Comp. Zool., vol. xi, p. 61.

parasiticus Hertwig, Rept. Chal. Exp., vol. vi, 1882, p. 116.

This interesting actinian is one of very few among our fauna having a definitely colonial habit. The species has a rather extended range of distribution, as may be inferred from the above list of references, and the recorded localities from Maine to Maryland. It is also more or less abundant, Verrill reporting "many thousands of specimens taken off Nantucket, Marthas Vineyard," etc. Its range of depth seems to be from 25 to 400 or more fathoms. The species, while most familiar in association with the hermit crab, has apparently considerable variability as to habitat. Verrill has reported them as in some cases investing the tubes of *Hyalinœcia*, in others forming a similar investment of stems or branches of *Paramuricia grandis*. Those taken in the Woods Hole region have all been associated with hermit crabs. Several species have been described, among them *E. parasiticus*, *E. papillosus*, *E. americanus*, *E. paguriphilus*, etc.; but it is safe to say that among these several are identical. And it may be doubted if of the entire list herein referred to there is hardly more than varietal distinction, the variation expressing for the most part the influence of the varying habitats of the examples concerned.

The many excellent figures of the species easily available in the reports of Verrill, Hertwig, and others, obviate any special necessity for a duplication in this report.

PARACTIS Milne-Edwards, 1857.

The genus was established by Milne-Edwards and has been distinguished by the following characters, given in merest outline: Body smooth, devoid of papillæ or marginal spherules, numerous longitudinal furrows on the column; tentacles of about the same size and character.

Paractis rapiformis (Lesueur).

Actinia rapiformis Lesueur, Jour. Acad. Nat. Sci., Phil., 1817, vol. 1.

Paractis rapiformis Milne-Edwards, Hist. Nat. des Corallaires, 1857, p. 249.

Actinia rapiformis Verrill, Mem. Boston Soc. Nat. Hist., vol. 1, 1864, p. 35.

Paraclis rapiformis Verrill, Inv. An. Vineyard Sound, 1873, p. 363, 738; Am. Jour. Sci., vol. iii, p. 436. Andres, Le Attnie, Fauna u. Flora Golfes Neapel, bd. ix 1883, p. 262. McMurich, Stud. Biol. Lab. Johns Hopkins Univ., vol. IV, p. 62.

Ammophilactis rapiformis Verrill, Am. Jour. Sci., 1899, vol. vii, p. 213. Parker, Am. Nat., 1900, vol. xxxiv, p. 753.

This species has not been taken by the present writer but is known to occur within the region. According to Verrill, its distribution ranges from North Carolina to Long Island Sound. The following brief description is taken from that of Verrill and may serve as a summary of the chief characters of the

species: "Surface nearly smooth, slightly sulcated lengthwise, color pale flesh color, or pink, translucent. Tentacles numerous, short, tapering, pale greenish olive, with dark band around the base, connecting with a dark line radiating from mouth." To this the author adds that its size when extended is 3 or 4 inches long, by about 1 inch in diameter.

BICIDIUM L. Agassiz, 1859.

Bicidium parasitica Agassiz [text fig. 2].

Bicidium parasitica L. Agassiz, Proc. Boston Soc. Nat. Hist., vol. VII, 1859, p. 24; Verrill, Mem. Boston Soc. Nat. Hist., vol. I, 1864, p. 31; E. C. and A. Agassiz, Sea-side Nat. Hist., 1865, p. 15.

Peachia parasitica Verrill, Proc. Boston Soc. Nat. Hist., vol. X, 1866, p. 338; Inv. An. Vineyard Isl., 1874, p. 739.
Philomedusa parasitica Andres, Le Attinie, 1884, p. 112.

Though reported by Agassiz and Verrill as more or less common in its relation as a parasite or commensal on *Cyanea arctica*, the writer has not found it on any specimens taken at Woods Hole. Verrill also reports it as having been found buried in gravel at low water at Eastport, Me. So far as I am aware, it has not been reported south of Cape Cod. Not having seen living specimens of the species the following description is compiled in part from the accounts of Agassiz and Verrill, and in part from specimens loaned by Mr. George M. Gray, who collected them at Eastport, Me. The figure was drawn from these specimens.

Figures of the shape as given differ somewhat, that of A. Agassiz showing a rather large oral end, and tapering to a rather small rounded point at the aboral. According to Verrill, it is more nearly barrel shaped. The size is about 35 mm. in length by about 10 mm. in largest diameter. Body with longitudinal furrows and "transverse wrinkles, by means of which it fastens itself securely among the fluted membranes around the mouth of the jellyfish." It is said to live for some time in confinement, where it attaches itself "for its whole length to the vessel in which it is kept, and clinging quite firmly if any attempt is made to remove it." This mode of adherence may be taken to imply the presence of such suckers as are more or less common in several other species of actinians. According to Verrill, it resembles very closely species of *Peachia* as described by Gosse.

ANEMONIA Risso, 1826.

Anemonia sargassensis Hargitt. [Pl. XLI, fig. 3.]

Anemonia sargassensis Hargitt, Biological Bulletin, vol. XIV, p. 117, 1908.

This anemone was briefly described in a recent note (vide supra), and some reference made to its habitat. Several other points call for further elucidation. Figure 3 of plate XLI shows well the general aspects of the creature and its mode of attachment to the gulf weed which forms apparently its chief or only habitat. The figure was made from life and gives approximately the color and aspects of average specimens. The base is adapted to clasping the stems of the weed to which it adheres with great tenacity. It is also able to creep along from place to place by means of the disk, though it does this only occasionally. A specimen in the aquarium was observed to remain in one identical spot for more than 30 hours. Another feature, more or less rare, is that of inflating the pedal disk, and thus making of it a float by means of which the creature may drift oral end downward, indefinitely. Duerden (1902) reports a similar habit in *Bunodosoma spherulata*, *Bunodeopsis antilliensis*, and cites observations of Duchassaing and Michelotti of a similar trait in *Cystiactis eugenia*. I have occasionally observed the same thing in several other actinians, but only in the artificial conditions of the aquarium; and it may not yet be improbable that this has something to do with the performance, yet its occurrence in nature may not be unusual. (Cf. also Gosse on this feature, p. 144.)

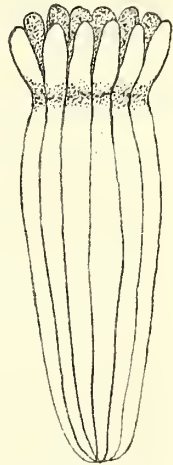


FIG. 2.—*Bicidium parasiticum*.

In 1833 Quoy et Gaimard, Voyage de l'Astrolabe (Zoologie, t. iv, p. 146), described a species, *Anemonia pelagica*, having several points in common with that here under discussion; for example, its pelagic habitat, "Trouvée sur des fucus au milieu de l'Océan Atlantique;" also the prehensile nature of the tentacles. Their description is, however, very vague and Andres regards the species as doubtful. Moreover, as compared with *A. sargassensis* it has many points of difference, such as color, number of tentacles, etc. (Cf. Milne-Edwards et Haime, Histoire Naturelle des Corallaires, t. 1, p. 235).

The following may be regarded as diagnostic characters: Column short and rather broad, in about the relation of 1 to 2, more or less fluted; pedal disk well developed and adapted to clasping stems of the weed; oral disk marked by radiating lines of flake white, or cream-colored lines varying in size and extending upon bases of tentacles; tentacles cylindrical, long and tapering, but slightly contractile, of various sizes and disposition about the margin of the disk; tentacles highly prehensile, and more or less adhesive, both of which characters seem of great importance as a means of catching prey, and in locomotion; tentacles variable in number, from 25 to 30 in smaller specimens to 50 in larger, and from 5 to 15 mm. in length, inner series nearly twice diameter of disk; in several cases bifurcated tentacles were observed. Tactile sense highly developed in larger tentacles.

Dimensions of body: An average of about 5 to 6 mm. high by 9 mm. in diameter. Color is various, though light brownish to chestnut or olivaceous tints are predominant. These with the whitish lines of disk and tentacles give a simulation to the color of the Sargassum in a most remarkable degree, so much so that unless careful scrutiny is made the specimens are certain to be overlooked. This feature they seem to share in common with many of the Sargassum fauna.

Acontia seem to be entirely lacking, no amount of irritation being able to secure their discharge; subsequent sections likewise failed to reveal their presence.

Primary mesenteries, six pairs (see pl. xli, fig. 3). The figure was drawn from a small specimen, and the secondary mesenteries are only slightly developed. Directives quite well marked as shown.

Sphincter very weak or lacking, rendering contraction slight, in no ease sufficient to withdraw the tentacles or wholly cover the oral disk. Body quite smooth, except for the slight vertical fluting referred to above; no tubercles or marginal spherules.

SAGARTIA Gosse, 1858.

According to Hertwig (Challenger Rept., vol. vi, pt. xv, p. 72), the genus *Sagartia* should be limited to those "*Sagartida* with smooth wall and numerous powerful tentacles arranged in several rows; without anatomically perceptible sinclides." This definition excludes several forms which have been hitherto usually referred to this genus, among them at least one of our local species, namely, *S. leucolena*, which has been referred by Andres to the genus *Cylista*.

Sagartia modesta Verrill. [Pl. xlii, fig. 5, 6; xliii, fig. 7.]

Sagartia modesta Verrill, Proc. Boston Soc. Nat. Hist., vol. x, 1866, p. 337; Inv. An. Vineyard Sound, 1874, pp. 330, 738.
Andres, Fauna u. Flora Golfes Neapel, bd. ix. Parker, Am. Nat., vol. xxxiv, 1900.

Body elongate, cylindrical, in expansion about five times longer than in diameter. Pedal disk more or less evident, effective as an organ of adhesion, by means of which it attached itself to a rock or other substratum. This may be best observed in a small aquarium, or by careful examination of specimens when first taken from the normal habitat, adherent to some supporting base. Tentacles are numerous, from 60 to 100, more or less marginal in several rows; they are slender and tapering, about twice the length of the diameter of oral disk, or perhaps slightly more. Color of tentacles pale grayish or greenish, with dark lateral spots near the base, and with lighter bars or bands toward the distal portion, interspersed with whitish bands or spots (pl. xlii, fig. 6). Oral disk yellowish or white, with darker radial lines; mouth with 15 to 20 rather prominent liplike folds. General color more or less variable; column pale flesh color. When first taken from the water or sand the body is often covered with a sheath of mucous and adherent sand grains. Acontia extruded over various portions of body, but without evident sinclides.

Habitat: The species has been found by me only in burrows on sandy and pebbly beaches usually just about or slightly below low-tide line, and always attached to a smooth cobblestone. In the aquarium it will adhere to almost any smooth support, or even the sides or bottom of the dish or aquarium.

Distribution: The species is accounted rather rare. This may be due in part to the burrowing habit and to the close simulation in color of the tentacles and oral disk as they appear at the mouth of the burrow, rendering difficult its detection unless one looks for it with some care. But I have not found it in any such numbers as to suggest it as a common or abundant species. Verrill reports its distribution from Long Island Sound to Vineyard Sound. I have also taken it in Buzzards Bay adjacent to Woods Hole.

***Sagartia luciae* Verrill.** [Pl. XLI, fig. 1 and 2.]

Sagartia luciae Verrill, Am. Jour. Sci., 4th, vol. VI, 1898, p. 493. Parker, Am. Nat., vol. XXXIV, 1900; *ibid.*, vol. XXXVI, 1902, p. 491. Davenport, Mark Mem. Vol.

This beautiful little actinian, formerly a stranger to the fauna of Woods Hole, is now one of the most abundant of the littoral species, occurring almost everywhere—on rocks, eelgrass, fucus, shells, piles, etc. It is a small species, varying from 10 to 18 mm. in height, by about 4 to 6 mm. in diameter. The body is smooth and highly contractile, dull olive greenish in color, with a variable number of vertical yellowish or orange stripes. Tentacles rather numerous, from 25 to 50, in several illy defined whorls, long and delicate, and very contractile, pale greenish, sometimes tinged with whitish. Oral disk variable as to shape and color; usually flat or concave, greenish, or sometimes with darker radial lines, and often with conspicuous bars at base of directive tentacles. It will more often be observed that only a single bar is present. This is due to the fact that a common mode of fission, to be mentioned later, often leaves but one of these bars apparent. Acontia freely extruded through body or mouth.

Reproduction: At certain times sexual propagation is active, and in his original description Verrill states that young embryos might be seen swimming in the cavity of the translucent tentacles. One may also find at certain times in sections of the animal the inclusion in the mesenteries of genital cells. So far as my own observation has gone, however, another mode seems to be of more general occurrence—an asexual one, namely, fission. I have repeatedly observed this process in all stages at almost any time during midsummer. It is not difficult, indeed, to observe the process from its inception to completion, for it goes forward with surprising rapidity, the entire operation occupying from two to three hours, probably often less time. This is most easily studied in small aquaria, or even finger bowls or other glass dishes capable of holding a pint or a liter of water.

Unlike the process which has been described for *Metridium* and a few other species, in which fission begins at the mouth or oral disk and proceeds vertically downward, in *S. luciae* the very opposite direction is the one invariably followed, at least so far as I have observed. The first evidence of such fission may be noted in an extension of the pedal disk in a plane parallel with the oral axis. If this extension is to initiate the process of fission there will soon be distinguishable the appearance of a constriction of this elongated disk and the organization of a sort of double foot, in which may be seen the radial arrangements of the proximal ends of the mesenteries. The stretching of the disk is followed by a corresponding condition of the walls of the column, a condition which will soon be seen to involve the entire body and oral disk. Careful observation will show a gradual thinning of the basal disk as the stretching goes on more and more, and sooner or later the actual rupture of the bottom of the disk, a rent appearing and passing in a direction at right angles to the oral axis. When this is clearly underway the pulling of the opposite halves of the body continues with increased vigor, and the rent may be followed in an upward and vertical direction, which enables the observer to actually see the inner organs, mesenteries, acontia, etc. A most curious phenomenon may be seen occasionally as the process continues, namely, as the pulling and consequent tearing proceeds there will occasionally be witnessed the explosion and shooting out of acontia, apparently in response to the physical stimulus involved in the rending of the tissues. It is as if at certain times the pulling was too vigorous and the consequent "hurt" more than the creature could stand with equanimity, and the extrusion of the acontia the expression of protest on the part of the

injured tissues. The process goes on usually without interruption till the fission has separated the basal portion completely, the last rupture of the lateral threads occurring with a more or less sudden break and the prompt contraction of the free ends.

The upward fission is fairly rapid, and soon the oral disk and mouth become involved in the operation. The fission is almost invariably finished upon one side at a time; that is, one half seems to yield more readily than the other, and the rending of the tissues of that side may be complete as much as a half hour before that of the other. Indeed, it would seem as if there was something of arrest in the vigor of the pulling when the fission had completed itself throughout one half. As the process of either side approaches completion the last vestige of the oral disk becomes spun out into a delicate thread 5 or 6 mm. or more long, in a tremendous state of tension, the final rupture of which takes place with a more or less sudden rebound of the ends and sides of the body. The final rupture of the other side seems to take place more slowly, but is soon accomplished, when the two halves of the divided actinian assume a more or less erect aspect, fold the edges inward until the opposite edges approximate and finally unite and gradually heal over, each becoming an independent individual. The healing and internal adjustments would seem to be much slower than the fission, appearing to require for completion a day or two, perhaps more in some cases.

That this process of propagation is a normal one and of general occurrence during the summer can hardly be doubted. The immense colonies which may often be found on a given stone, or on a shell of *Mytilus*, could hardly have happened thus by other mode. Furthermore, when one seeks for perfectly symmetrical specimens in a state of nature they are difficult to find. The figure shown in plate XLI, made from a living specimen, illustrates the asymmetry in the single white line connecting the directive tentacle of only one side. But this is not all. Sections of the body show the asymmetry to involve the whole internal organization—mesenteries, siphonoglyphes, etc.

In most cases the species is normally diglyphic; but during the season of asexual propagation this feature is more or less obscured or disguised. Further reference to figure 1 will make this point more evident. I have occasionally found triglyphic individuals, but they are rather unusual. One such was observed undergoing fission, and in this case the process involved very nearly an exact third of the parent body, leaving an unsymmetrical diglyphic specimen. I was somewhat curious to see whether a fission into three individuals at once might not occur, but this did not happen; and though the specimen was followed during two or three succeeding days there was no indication of further fission.

Carlgren (1904) in a recent paper has described experiments and observations on several species of actinians which have interesting features in common with those herein described. On page 77 he gives some account of fission found occurring in nature, and certain of his figures might be duplicated by this phenomenon in *S. luciae* (e. g., fig. 6, 24, 25, 26, 27, taf. I and II.)

The mesenteries of this species vary greatly in number and arrangement. I had the privilege of looking over a large number of sections made by Mr. D. W. Davis, who has been engaged in experiments upon it, and sought in vain for a single case of what might be regarded as typical hexamerous symmetry.

Distribution: The species was first described by Verrill in 1898. It was first observed at New Haven about 1892, and was then quite rare. Within the past 10 years, to the personal knowledge of the writer, the occurrence of the species at Woods Hole has passed from a condition of comparative rarity to one of extreme abundance. A brief paper by Parker (1902) gives a succinct account of its dispersal along the coast since its first occurrence about New Haven. Apparently the same species has been recently found at Plymouth, England (1908), and a few brief comments made to the effect that instead of having got its introduction into our region and spread from that as a center, the fact would seem to be that it had found distribution from some unknown source and had been simultaneously scattered and established in several remote localities. Mr. Davis has recorded the species at San Francisco, and states that its identity with *S. luciae* seems beyond question. I looked in vain for it at South Harpswell, Me., in 1909.^a

^a The writer identified this species at Naples in 1911, having the same distinctive features of structure, color, mode of fission, etc. This would seem to show that it is probably very widely distributed over the shallower seas.

Habitat: Very general. It seems to find itself at home almost anywhere—on rocks in tide guts, brackish ponds, upon eelgrass, on living shells of *Mytilus*, among colonies of *Molgula* and *Cynthia*, and others too numerous to mention.

***Sagartia abyssicola* Verrill.**

Sagartia abyssicola Verrill, Am. Jour. Sci., vol. XXIII, 1882, p. 314; Bull. Mus. Com. Zool., vol. XI, 1883, p. 45. Parker, Am. Nat., vol. XXXIV, 1900.

Assuming a valid significance in the name of this species, its habitat might seem to carry it easily beyond the scope of this report. It has, however, become so familiar from recent collections, and from depths in no sense abyssal, that it seems very proper to make at least a brief record of its occurrence.

In view of the excellent descriptions and figures given by Verrill (vide supra), there is no occasion for attempting anything of the sort here. Its more usual habitat is the tubes of the annelid, *Hyalinæcia artifax*, but it is occasionally found attached to stones, shells, etc. When brought up in the dredge it is almost invariably contracted into a low conical lump, resembling more or less a small *Metridium* in a state of close contraction. The tentacles are numerous, longer than the diameter of the body, slender, and tapering. Acontia are numerous and protruded freely. The color is usually a dull brown in preserved specimens.

Distribution: Various records show it to be more or less common along much of the coast line, at depths of 50 to 60 fathoms and beyond.

CYLISTA Gosse, 1860.

***Cylista leucolena* Verrill. [Pl. XLIII, fig. 8.]**

Sagartia leucolena Verrill, Proc. Boston Soc. Nat. Hist., vol. x, 1866, p. 336; Inv. An. Vineyard Sound, 1874, pp. 329, 738; Am. Jour. Sci., 4th, vol. VI, 1898, p. 495.
Cylista leucolena Andres, Fauna u. Flora Golfes Neapel, bd. IX, p. 151. Parker, Am. Nat., vol. XXXIV, 1900.

This species is common and abundant throughout the region, but its small size and retiring habits tend to render its presence more or less obscure or even unknown.

The following characteristics may be regarded as diagnostic. Body elongated, cylindrical even in contraction, smooth, or with minute papillæ disposed in scattered but more or less vertical rows. Pedal disk well developed, by means of which the creature may adhere tenaciously to almost any object, and also serving as a means of locomotion. Oral disk concave, mouth with about 10 pairs of corrugations, or lips, which are of a brownish color. Body translucent, enabling one to observe the mesenteries which appear as whitish longitudinal lines within the body. Tentacles rather numerous, 40 to 60 or more, in some three series, the inner longest, all delicate, attenuate at tips. Color usually delicate pinkish or flesh color to almost white, sometimes with a greenish tinge, especially near oral end and bases of tentacles when contracted;^a tentacles whitish, often greenish at basal ends. Size variable according to age, the average being about 30 to 40 mm. in height by about 5 or 6 mm. in diameter.

In a few points this description does not wholly agree with that of Verrill. For example, the size ranges somewhat smaller, Verrill giving the height as from 50 to 65 mm. Again, his statement that "one of the primary tentacles in the longitudinal plane opposite one end of the mouth is much longer than the others, and often differently colored than the others," I was not able to confirm, except in a rare specimen now and then. Surely it can not be regarded as a diagnostic feature. It was not unusual to find at certain times that one or even several of the tentacles of the inner series might become more

^a Occasionally an interesting variety of this species is found, distinguished by a marked color difference, specimens being bright or deeply orange colored. A few specimens were taken at Woods Hole and at first taken to be a new species; but a study of sections failed to show any structural distinction of consequence.

Later I received from Miss Anna Luther, of Jersey City, several living specimens which had been taken at Bay Shore, Long Island, and all of the same distinct orange coloration. At this locality the orange color predominates, only an occasional specimen of the white variety occurring. They are quite hardy and live in a balanced aquarium for months if occasionally fed. In this they are quite like the white variety of Woods Hole. So far as I am aware this marked color distinction has not hitherto been pointed out.

or less specialized at times, apparently serving as tactile organs, being greatly extended and vigorously vibrated in various directions. Figure 8, plate XLIII, will give a good general impression of the appearance of the animal.

Habitat: More or less common on rocky or gravelly beaches adhering to the under side of rocks, or in crevices; also found among masses of ascidians on piles of docks, and among colonies of sponges, worm tubes, etc. It is quite susceptible to light and invariably seeks shaded or protected localities. They are much more commonly found under stones along rocky beaches than elsewhere. They are readily adaptable to an aquarium habitat, living in apparently normal vigor for several weeks if some care be taken to provide fairly good water and occasionally some shreds of meat, as bits of shrimp or clam, etc. In this habitat it is quite easy to study the habits of the organism to one's content. Elsewhere I have given some account of their behavior in relation to light intensity, etc. Specimens occasionally adopt a burrowing habit and secrete themselves in sand.

Reproduction: This seems to be wholly of the sexual sort. During several years of fairly close observations I have never seen the slightest indications of budding or fission. Furthermore, the sexes seem to be quite distinct. I have repeatedly undertaken to study the development of the species, but have found it difficult to secure ripe males and females at the same time. Only once have I succeeded in getting early traces of cleavage. Whether the transfer of specimens to the aquarium tends to check the reproductive function I am uncertain. I have repeatedly had eggs deposited in the dishes, and in a few cases sperms were deposited at the same time, but in only one instance have normal fertilization and development followed. I have had a similar experience with other actinians, e. g., *Metridium*, and am disposed to regard the transfer to an artificial condition as tending to check or modify the sexual activity. An examination of sperms obtained under these circumstances showed them to be quite active and apparently normal; but attempts to fertilize eggs liberated at the same time seldom gave any response.

Distribution: This is given by Verrill as from North Carolina to Cape Cod. I have taken them in Long Island Sound and in Vineyard Sound, Buzzards Bay, etc.—a fairly abundant species throughout the entire region.

TEALIA Gosse, 1858.

Tealia crassicornis Muller. [Text fig. 3 and 4.]

Actinia crassicornis Muller, 1776; Gmelin, 1788, 1793, 1798; Johnston, Hist. Brit. Zooph., 1847, p. 226.

Rhodactinia davisii Agassiz, Compt. Rend., 1847, p. 677; Verrill, Mem. Boston Soc. Nat. Hist., vol. I, 1864, p. 18.

Bunodes crassicornis Gosse, Ann. Nat. Hist., 1855, p. 294.

Tealia crassicornis Gosse, ibid., 1858, p. 417; Actinologia Britannica, 1860, p. 209.

Andres, Fauna u. Flora Golfes v. Neapel, bd. IX, p. 199.

The synonymy of this species is extremely intricate and confusing. It may be doubted whether in the entire literature of Actiniaria a more complicated case can be found. This may be due in part to the highly variable external features, which have been so largely taken by the early naturalists as diagnostic. No attempt has been made to present more than the briefest outline in the above list. To those who are concerned as to this feature fuller details may be found in the masterful work of Andres (vide supra).

In connection with the above reference to the variable aspects of the species it may be well to cite certain facts. For example, Verrill had long ago pointed out this feature, saying "in form it is very mutable, both ends being capable of great distension or contraction. It will often assume a variety of the most diversified forms within a very few minutes." As to color he makes similar reference: "Deep crimson, mottled with pink; littoral specimens most commonly of a clear bluish-green color, irregularly blotched with crimson or reddish brown." The specimens taken by me, though comparatively few, have shown similar variability, especially as to coloration. I have not observed the extreme variation of form mentioned by Verrill. It should be stated, however, that my specimens were mostly of small size, and being dredged from a depth of some 20 fathoms were more or less contracted, only a few of them living long after being taken and these apparently not extending fully in the aquarium.

In only a few instances have representatives of the species been taken in the region. On two occasions I have taken specimens at Crab Ledge, off Chatham, Mass.; another specimen was taken by Dr. Sumner, late in the summer of 1907, off Gay Head, which was presumably of this species, though unfortunately was not preserved.

The following may be taken as fairly diagnostic characters: Column generally smooth, or with slight papillose bodies variously disposed over the body, more particularly on the upper portion, and in the specimen there was a marginal series of spherular bodies. Pedal disk well developed and larger than diameter of column. Oral disk well defined and with darker radial lines extending toward the margin. Tentacles rather stout, fingerlike, about 50 in number in specimens taken by me, arranged in some three series.

Sphincter strongly developed, and almost diagrammatically comparable with Hertwig's figure of this organ for the genus. (Cf. fig. 4.) I regret that my material was found badly preserved for histological details, so that it has been found impracticable to submit figures of other internal organs. It was not difficult to determine the presence of numerous mesenteries, two siphonoglyphes, and the appropriate directives, as shown in text figure 3.

Reproduction: So far as known this is exclusively sexual. In the cases under observation it was found that earlier development takes place within the gastric cavity of the adult. Several young were brought forth during life in the aquarium in a stage of perfect development, and continued to thrive for some time.

Distribution: While rather rare within the region the cases given make certain its presence as an integral feature of the fauna. According to Verrill, from Nantucket Shoals to Grand Manan.

ELOACTIS Andres, 1883.

Eloactis producta (Stimpson). [Pl. XLII, fig. 4.]

Actinia producta Stimpson, Proc. Soc. Nat. Hist., Boston, vol. v, p. 110, 1856.

Halcampa producta Verrill, Mem. Boston Soc. Nat. Hist., vol. 1, 1862, p. 30.

albida Verrill, *ibid.*, p. 29.

producta Verrill, Inv. An. Vineyard Sound, 1874, pp. 330, 738. Andres, Fauna u. Flora Golfes v. Neapel, bd. IX, p. 106.

Eloactis producta McMurrich, Proc. U. S. Nat. Mus., vol. XVI, 1894, pp. 141-142.

Eloactis producta Parker, Am. Nat., vol. XXXIV, 1900.

Andres (op. cit., p. 106) was the first to express doubt as to the exact generic relations of this actinian and to suggest the probable necessity of establishing a new genus. This suggestion was later

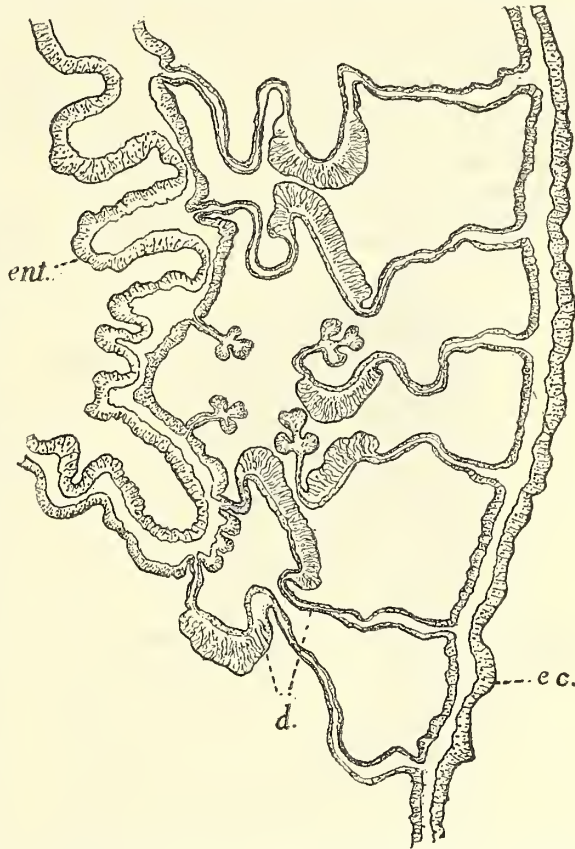


FIG. 3.—*Tealia crassicornis*. Section through two primary, and pair of directive mesenteries; *ent*, entoderm; *ec*, ectoderm; *d*, directive mesenteries.

acted upon by McMurich (*vide supra*), who proposed its reference to the genus *Eloactis* of Andres. This was later followed by Parker, and following these proposals I have formally accepted this reference. At the same time it should be said that the grounds of the proposed reference to another genus are not altogether conclusive. Whether a given species be hexamerous or decamerous, in view of the range of variation now known to prevail to considerable extent, can hardly be of great significance as a taxonomic feature. While the species under consideration is apparently predominantly decamerous, I have found considerable variation in this respect. In younger specimens the hexamerous condition is not at all uncommon. In several different specimens some 50 to 70 mm. in length which I took occasion to section and examine the hexamerous state was prevalent. In very large specimens the decamerous arrangement was quite as prevalent.

The general features of the species will be fairly well shown in figure 4, plate XLII. As will be seen, the body is elongated, more or less cylindrical, and comprises some three distinguishable regions:

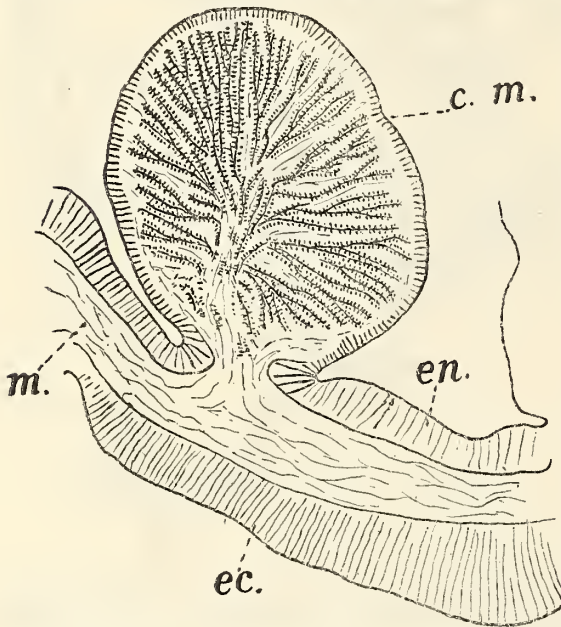


FIG. 4.—*Tealia crassicornis*. Section of circular muscle (*c. m.*); *en.* entoderm; *m.* mesoderm; *ec.* ectoderm.

An oral, retractile portion, or capitulum; a basal, bulbous portion, or pedal-like disk, or physa; and an intermediate portion, the column. This is marked by a series of about 20 longitudinal grooves, whose intermediate ridges are provided with numerous papilliform suckers, by means of which the creature is able to retain itself in the burrow. The length of the body varies greatly, averaging perhaps 100 to 150 mm. in ordinary life. In some cases at full extension it may become twice this length (Verrill). The diameter also varies greatly. It probably averages about 8 to 10 mm. The tentacles are normally 20 in number, with occasional variations, rather stout, with brownish knob-like tips. The color varies from whitish to pale salmon on the column, the base translucent, with bluish tint. A white variety has been described under the name *Halcampa albida*; but this is doubtless a merely varietal character, and in nowise entitled to specific distinction.

Habitat: The species is characterized in a remarkable degree by the burrowing habit.

In many years of observation I have never found it except in burrows on sand flats

between tide lines. In this habitat it forms burrows wherein it lives, perhaps more or less permanently. However, it should be said that specimens in the aquarium, in which, by the way, it will thrive for weeks in apparent vigor, yet show a tendency to emerge from the burrows at night and to migrate variously about the aquarium. A further fact may not be without some significance to the same effect, namely, that its burrows do not become lined by a tubular product, such as is provided by *Cerianthus*. I have elsewhere (Biological Bulletin, vol. XII, p. 274) pointed out certain peculiarities of behavior of some significance in this connection, and also as indicating something as to modes of life. That it is markedly sensitive to varying degrees of light, even to the extent of distinguishing between light and darkness, which has rendered the species predominantly nocturnal, seems to be beyond doubt.

These two features, namely, the burrowing and nocturnal habits, conspire to render its presence unknown by most people, except those who especially direct attention to its discovery. While more abundant locally than either *Sagartia modesta* or *Edwardsia elegans* it is yet far from common.

It may be suggested in this connection that the act of burrowing is effected exclusively by the aboral end, or physa. This is bent downward upon the sand, and then by a process of pushing, and at the same time a twisting motion, and by alternate contractions and expansions of the disk, the foot is forced downward. It is by no means a rapid process, and very differently effective by different individuals, as I have elsewhere shown (op. cit.).

Distribution: Verrill reports it from South Carolina to Cape Cod. I have taken it at certain points in Buzzards Bay, and at Catama Bay, and elsewhere about Marthas Vineyard. Its distribution would seem to be more or less local, and dependent upon favorable conditions as to food and for burrowing, etc.

EDWARDSIA Quatrefages, 1842.

Edwardsia elegans Verrill. [Text fig. 5 and pl. XLIV, fig. 12.]

Edwardsia elegans Verrill, Am. Journ. Science, ser. 2, vol. 48, p. 118. Andres, Fauna u. Flora Golf. v. Neapel, vol. ix, p. 95. Parker, Am. Nat., vol. xxxiv, p. 749.

This elegant little actinian is seldom seen except by those who diligently search for it, its burrowing habit giving it effective seclusion.

Body elongate, comprising three more or less distinctive portions, namely, (1) an upper, smooth, necklike portion, of faint brownish color; (2) the body or column, rough from the presence of a sandy accretion over a tough cuticular covering; (3) a somewhat roundish basal portion, translucent or of slightly bluish tint. The entire body is marked by 8 longitudinal grooves or sulcations. Tentacles 16, rather short and fingerlike in moderate contraction, or long and delicately attenuate when fully expanded; apparently of two series, an outer, which is usually depressed close upon the sand at the mouth of the burrow; and a second, alternating series, which extend upward. In color the tentacles are pale brownish, with transverse bars or blotches whitish or pale greenish.

Length of body in expansion 20 to 35 mm., diameter 3 to 5 mm. The organization of the body is shown in the sections taken through the oesophageal region. (Pl. XLIV, fig. 12.)

Distribution and habitat: Found generally throughout the region in favorable sand flats between tide lines, where it burrows. Taken at West Falmouth, Woods Hole, Great Pond, Falmouth, etc.

In a paper on the "Behavior of sea anemones" (Biological Bulletin, vol. xii), I have given some account of phases of activity as exhibited by tube-dwelling anemones. At the time this paper was prepared I had not been able to include any account of this species. This was later included in a report upon the reactions of these organisms given at the International Zoological Congress, Boston, 1907. It may suffice in this connection to say that in almost every respect the reactions and behavior of *E. elegans* are comparable with those of *Sagartia* and *Eloactis*.

The species lives well in aquaria and affords a favorable object upon which to observe various aspects of behavior. This is particularly the case with food taking and reactions to varying degrees of light intensity.

Edwardsia sipunculoides (Stimpson) Verrill.

Actinia sipunculoides Stimpson, Marine Inv. of Grand Manan, 1853. *Edwardsia sipunculoides* Verrill, Mem. Soc. Nat. Hist., Boston, vol. i, p. 28, 1864; Andres, Fauna u. Flora Golfes Neapel, bd. ix; Parker, Am. Nat., vol. xxxiv, 1900.

This species has not hitherto been recorded south of Cape Cod. The writer several years ago found a single specimen of an *Edwardsia* at West Falmouth, Buzzards Bay, which was thought to be *E. sipun-*

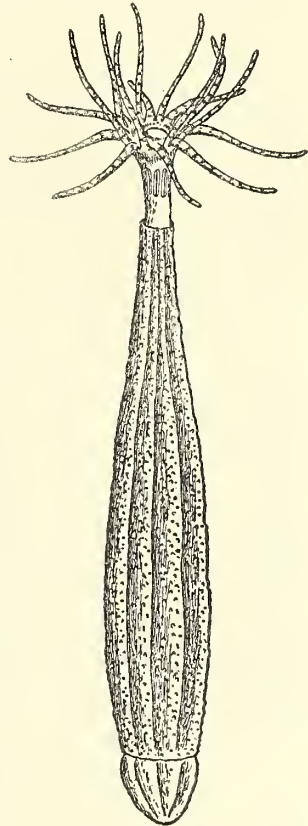


FIG. 5.—*Edwardsia elegans*.

culoides, but in some way it was lost before any decisive identification was made, and hence the matter must remain somewhat doubtful. During the present summer (1909) I took a single specimen at South Harpswell, Me., of exactly the same general characters, and conforming so far as distinguishable with the descriptions of Stimpson and Verrill. When first dug out of the sand the specimen was about 50 to 60 mm. in length, of whitish or pale flesh color. After it was placed in the collecting pail along with a few other objects it became greatly contracted and remained in that condition for more than a week in the laboratory, though every means available to induce it to expand was tried. Finally, before leaving it was killed and preserved, and later carefully sectioned in the hope of finding conclusive evidence as to its specific relations. Unfortunately the state of contraction had been so great that the killing proved to have been unsatisfactorily done, and while the main generic features were easily distinguishable it was not practicable to certainly determine the number of tentacles and other specific characters. So far as known only one other species could be possibly confused with it, namely, *E. farinacea*, and it seemed not to have been this. I am strongly convinced that the specimen was *E. sipunculoides*, and that, moreover, the one taken at Woods Hole previously was also this species. Hence it seems altogether proper to include the species as coming within the region.

I much regret that I am not able to present good anatomical descriptions of the species. However, the earlier description of Verrill (vide supra) renders this lack less serious.

Edwardsia lineata Verrill.

Edwardsia lineata Verrill, Inv. An. Vineyard Sound, p. 739, 1874; Andres, Fauna u. Flora v. Golf. Neapel, bd. ix; Parker, Am. Nat., vol. xxxiv, 1900, p. 750.

"Body cylindrical, elongate, covered with dirty brownish, slightly wrinkled epidermis, except just below tentacles, where it is smooth, translucent, and usually with eight longitudinal, flake-white lines showing through. Tentacles 24 to 30, or more in large specimens; slender, tapering, obtuse, white or pale flesh color, each with a flake-white longitudinal line along inner side. Disk with white circle around the mouth, and often with eight or more radiating white lines extending to the base of inner tentacles; border of mouth somewhat pale red; naked part of column pale flesh color, often with circle of white below bases of tentacles. Length 25 to 30 mm., diameter 2.5 to 3 mm. Species remarkable in lacking any naked basal portion, or any true disk for attachment. This may be due to the peculiar habit of nestling in crevices between rocks, worm tubes, etc. Off Gay Head, 6 to 12 fathoms, among ascidians and annelid tubes, etc. Abundant."

I have not seen this species, and the above description has been compiled from that of Verrill. Having been on constant lookout for the species for several years, it seems rather strange not to have obtained a single record of its occurrence.

Edwardsia leidyi Verrill.

Edwardsia leidyi Verrill, Am Jour. Sci., ser. 4, vol. vi, p. 493; Parker, Am. Nat., vol. xxxiv, 1900, p. 750.

This remarkable Edwardsian was first noted by A. Agassiz as a parasite in *Mnemiopsis leidyi* and taken to be a leechlike worm. (Cf. Catalogue of North American Acalephæ, p. 23.) It was later observed by Verrill. (Invertebrate animals of Vineyard Sound, p. 457.) Its true character seems first to have been recognized by Mark. (Memoirs of Museum Comparative Zoology, vol. ix, p. 43.) Mark also pointed out the fact that this stage was a larval one, and that during this period it was a true parasite within the ctenophore. Following the development so far as conditions made it possible, he suggested that the larva might not improbably be a stage in the life history of *Edwardsia lineata*. To the present writer it seems rather more probably related to *E. elegans*. As evidence of this may be noted the number of tentacles in Mark's oldest specimen, namely, 16, while in *E. lineata* the number is from 24 to 30, or more. Again the aspect of the tentacles is very much like that of *E. elegans*.

It is much to be regretted that as yet we are without a final account of the life history, no later observer having been able to carry the record beyond that at which it was left by Mark. The present writer has sought to discover some clue to the later stages, but without success. The occurrence of the larvæ is most erratic. During some seasons it abounds to such extent that hardly a specimen of *Mnemiopsis* can

be found without from one to a half dozen or more of the parasites within the canals, and during other summers scarcely a single specimen can be found at all. During the entire summer of 1907 the writer sought from June to September for larvæ, but without finding a trace. In November of the same year Mr. Vinal Edwards and Dr. Sumner found them in immense numbers, almost every ctenophore being infected.

Morphology of the larval stage: Polyp slender and wormlike, and variously coiled in the canals of the ctenophore. Length of larger specimens 20 to 30 mm., diameter 1 to 2 mm., varying under conditions of contraction. Tentacles 16 (?), color pinkish or flesh color.

CERIANTHUS Delle Chiaje, 1841.

Cerianthus americanus Verrill. [Pl. XLIV, fig. 10.]

Cerianthus americanus Verrill, Mem. Boston Soc. Nat. Hist., vol. 1, 1866, p. 32; McMurrich, Jour. Morph., vol. IV, 1890, p. 131; Parker, Am. Nat., vol. XXXIV, 1900, p. 756.

Originally described by Verrill from a southern habitat, this species has but rarely been found at Woods Hole. The writer found a single specimen several years ago, but failed to secure it. In a collection of *Edwardsia* taken at Ram Island, Woods Hole, in 1902, there was found a single specimen which was turned over to the writer for identification. It resembled at first a specimen of *Sagartia leucolena*, or a very small specimen of *S. modesta*. A careful examination of the specimen, however, proved it to be an immature specimen of *Cerianthus*. The size was only about 35 mm. in length by about 5 mm. in diameter, in contraction. Sections showed no signs of gonads, and there were but 45 to 50 tentacles; all of which go to show a condition of immaturity. The sectional figures were made from the specimen and leave no doubt as to its identity.

The specimens originally described by Verrill were of very large size—2 feet or more in expansion. McMurrich, who has studied specimens from the same general region, has not been able to confirm Verrill's account as to size. Specimens examined by the writer from the Woods Hole region agree very closely with McMurrich's account in this particular. His account gives the length as not more than 20 cm., with a diameter of 1.5 to 2 cm.

In the matter of color there seems to be considerable variation. The specimen from which this account is chiefly derived was in life translucent and pale flesh color. Another specimen examined by the writer was brownish, especially near the oral portion, the aboral region being paler. A purplish tint is not unusual along with the brown.

Habitat: This seems to be almost exclusively at or just below average tide line and in muddy flats. The species is of burrowing habit, these burrows extending at an angle for considerable depths. The creature secretes a tubular lining for its burrow, which is composed of mucus secreted by ectodermal glands, in which are also agglutinated extruded nematocysts, grains of sand, etc. In the aquarium the specimens also secrete a similar tube, but, according to McMurrich, of much lighter texture.

ACTINAUGE Verrill, 1883.

Actinauge verrilli McMurrich.

Actinauge nodosa, Verrill, Am. Jour. Sci., vol. VI, 1873, p. 440; Bull. Mus. Comp. Zool., vol. XI, 1883, p. 50.
Actinauge verrilli, McMurrich, Proc. U. S. Nat. Mus., vol. XVI, 1893, p. 184.

Among the collections at Woods Hole I found four specimens of this species, two of which were taken by the *Albatross* in 1885 at station 2506 from a depth of 27 fathoms. The other two were taken by the *Fish Hawk* in 1899 at station 7070. These specimens differ more or less in general external features. The *Albatross* specimens (contracted) measured 5 and 7 cm. in height by about 4 and 5 cm. in diameter. The warty nodules, or verrucæ, were very prominent and characteristic. They were disposed in about 24 longitudinal rows in the smaller specimen. The capitular ridges were somewhat less evident and definite but about 40 in number. The larger specimen was much more contracted, making it impracticable to determine exactly the number and disposition of these structures, but the longitudinal rows seemed to be about 28 in number.

In the *Fish Hawk* specimens the verrucæ were much less prominent, and the capitular ridges and longitudinal rows likewise indistinct and correspondingly indefinite. They appeared, therefore, of smoother and cleaner texture than the former, which were rough and the furrows and nodular interstices coated with a brownish deposit in marked contrast to the whitish points of the nodules themselves.

While this species is seldom seen among the fauna of the region as strictly interpreted, still it has seemed quite proper to make at least a brief reference to their presence among contiguous fauna.

MADREPORARIA.

Of the Madreporaria there are comparatively few species which come within the range of the present synopsis. Of these by far the most common is *Astrangia*, which abounds almost everywhere. The more characteristic features of the order have been given in an earlier section.

ASTRANGIA M. Edwards and Haime.

Corallum forming an encrusting mass over the substructure, the colony forming variously disposed aggregates of polyps, mostly of small dimensions, though occasionally branching in rather complex fashion, as shown in figure 9, plate XLIII. The polyps are very transparent, but appear white as viewed against a dark background.

Astrangia danæ Agassiz. [Pl. XLIII, fig. 9.]

Astrangia danæ Agassiz, Proc. Am. Assoc. Adv. Sci., vol. II, p. 68, 1847; Milne-Edwards and Haime, Ann. des Sci. Nat., 3d ser., T. XII, 1850.

Astrangia astreiformis Leidy, Jour. Acad. Nat. Sci., vol. III, 1855, p. 139.

danæ Verrill, Mem. Boston Soc. Nat. His., vol. I, 1864, p. 40; Inv. An. Vineyard Sound, 1874, p. 740.

This is the best-known coral, having a natural habitat within the region. Indeed, it is the only one at all familiar along the shore waters of the New England coast. It occurs almost everywhere, growing on rocks, piles of docks, shells, etc., at or just below low-water line to a depth of 15 to 20 fathoms. Its range is given as from Florida to Cape Cod. It has also been reported from the waters of Casco Bay, Me. The species forms irregular incrustations of rather small dimensions over shells, rocks, etc., though it occasionally becomes larger and branches in rather complex fashion. It lives well in the aquarium for an indefinite time. Polyps in expansion about 10 to 15 mm. in height and with about 24 delicate tentacles, which bristle with nematocysts, especially about the tips. Cells of the corallum rather shallow and with numerous septa, as shown in the figure. The breeding season seems to be chiefly in midsummer. I have occasionally obtained eggs in the aquarium but it has been found difficult to secure them under conditions favorable for development.

ORBICELLA Dana, 1846.

Orbicella acropora (Linnaeus).

Madrepora acropora Linnaeus, Syst. Nat., x ed., p. 708.

Madrepora annularis Ellis & Solander, Nat. Hist. Zooph., 1786, p. 169.

faveolata Ellis & Solander, op. cit., p. 166.

Heliastrea annularis M. Edwards & Haime, Hist. Nat. Corall., vol. II, p. 473, 1857.

acropora Milne-Edwards & Haime, op. cit., p. 477.

Astrea annularis Lamarck, An. sans Vert., 2d ed., vol. II, p. 405.

Orbicella annularis Pourtales, Mem. Mus. Comp. Zool., vol. VII, 1880; A. Agassiz, Bull. Mus. Comp. Zool., vol. XX, p. 61, 1890.

acropora Vaughan, Bull. U. S. Fish Comm., vol. II, p. 301, 1901.

A fragment of this coral was found by Dr. F. B. Sumner on the beach at Nobska (Woods Hole) in July, 1906, and still another some two years later. Both specimens were somewhat worn by water action, yet easily identified. So far as known, the species has not hitherto been recorded north of Bermuda, Porto Rico, or similar range. And while at first I was disposed to regard its occurrence here as accidental, possibly through tourist agency, still the facts seem to warrant recording, leaving to

subsequent events the determination of its relation to the region. The specimen measured about 50 by 85 mm., and while more or less eroded was in good state of preservation. The extended dredgings made in the waters of Vineyard Sound for many years would seem to have made more or less certain its discovery if native to these waters. Vaughan's description of the species from Porto Rico gives no account as to depth from which taken, but merely the locality (Mayaguez) and from reef. Its habitat is probably quite shallow, and the course of the Gulf Stream in the region of Woods Hole might warrant its northern range. However, speculation is uncalled for; the facts are given for what they are, as suggested above.

ALCYONARIA.

The alcyonarian fauna of the region is so limited in species as to call for only passing notice. At most but two or three species are represented—one under the genus *Alcyonium* and perhaps two under the genus *Penatula*. In the deeper waters adjacent to Nantucket and off Marthas Vineyard the group has numerous representatives, accounts of which may be found in the reports of the dredging operations of the *Albatross* and *Fish Hawk* from 1880 to 1898. But as recent collections have added no additional facts, either as to species or distribution, it will suffice to call attention to the above reports.

It seems well to briefly describe the two species more likely to be met with by the student, though without attempting details as to structure and habits.

ALCYONIUM Linnæus, 1758.

Linnæus, Syst. Nat., Ed. x, vol. 1, p. 803.

Dana, Zoophytes, 1846, p. 611.

Milne-Edwards, Corallines, 1857.

Corallum fleshy, with granular spicules which do not project beyond the surface; base more or less enlarged and adherent to rocks, shells, etc. Colony variously branched, the branches thick and fingerlike, stem more or less devoid of polyps, which are abundant on the branches and terminal portions, and retractile within the cœnosarc.

Alcyonium carneum Agassiz.

Halcyonium carneum Agassiz, Proc. Am. Assoc. Adv. Sci., 1850, p. 209.

Alcyonium digitatum Stimpson, Marine Inv. Grand Manan, 1853, p. 7; Smithsonian Contr., vol. vi.

Alcyonium carneum Verrill, Mem. Boston Nat. Hist., 1866, vol. 1; Inv. An. Vineyard Sound, p. 497, 737.

This conspicuous alcyonarian is well known to almost every collector along the New England coast who has paid attention to the cœlenterate fauna to any extent. It is rather common from Vineyard Sound northward to Maine and beyond, occurring on rocks, shells, etc., and in depths of from 10 to 30 fathoms. It shows small adaptability to aquarium conditions, soon dying when placed therein. The color is variable, from pale flesh color to bright pink or reddish or orange. The colony is branched variously, the branches thick and fingerlike, from which probably arose the common name, "dead men's fingers," often used by fishermen. The stem is attached by an expanded base to any convenient support, such as shells, etc. Polyps variously distributed over upper portions of stem and branches, and in expansion rather conspicuous, having a length of from 7 to 10 mm.; they are highly contractile, and capable of entire retraction within the cœnenchyma. The tentacles are eight in number, beautifully fringed with delicate lobes so characteristic of the order.

PENNATULA.

Pennatula aculeata Danielson and Koren.

Pennatula aculeata Danielson and Koren, Forhandl. Vidensk. Selsk, 1858; same authors, Fauna Litt. Norv., iii, 1877. Verrill, Am. Jour. Sci., 1873.

This species was taken by the *Fish Hawk* at several stations off Marthas Vineyard and Block Island in 1882 and 1899, several specimens being now in the collection at Woods Hole. This is a well-known and very beautiful pennatulid; stems usually bulbous at base, the bulb larger at the proximal end,

rachis rather larger in median portion; general shape featherlike, hence the name; polyps borne on upper portion of the pinnæ. The colony varies in size from 10 to 25 cm.; color beautiful purplish red, bulb whitish and opaque in preservation. Species widely distributed over both eastern and western Atlantic and along the entire New England coast and south to Chesapeake Bay.

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DESCRIPTION OF PLATES.

PLATE XLI.

- FIG. 1. *Sagartia lucia*, general view from side. $\times 2$.
FIG. 2. *Sagartia lucia*, oral view, showing whitish lines marking position of œsophageal grooves, and on the left the evidence of recent fission of specimen as shown in dim outlines of the disk markings.
FIG. 3. *Anemonia sargassensis*, drawn and colored from life, showing also the clasping aspect of pedal disk.

PLATE XLII.

- FIG. 4. *Eloactis producta*, drawn and colored from life, showing the expanded disk, the smooth, pinkish lower and papillose upper portions of the column.
FIG. 5. *Sagartia modesta*, drawn and colored from life, showing expanded pedal disk, numerous tentacles, and the sinuous aspect of body as freely expanded in aquarium.
FIG. 6. Single tentacle of specimen, showing characteristic markings. $\times 3$.

PLATE XLIII.

- FIG. 7. *Sagartia modesta*, photograph from life as expanded in aquarium, the pedal disk attached to bottom under layer of sand.
FIG. 8. *Cylista leucolena*, photograph from life, in aquarium.
FIG. 9. *Astrangia danae*, an unusually large coral mass of this species. $\times \frac{1}{2}$.

PLATE XLIV.

- FIG. 10. *Cerianthus americanus*, section through œsophagus, showing groove and numerous mesenteries and their distribution; *oe*, œsophagus; *ec*, ectoderm.
FIG. 11. *Cylista leucolena*, section through œsophagus, showing paired grooves, mesenteries, and directives (*d*), and secondary mesenterial buds.
FIG. 12. *Edwardsia elegans*, section showing distinctive mesenteries and paired directives (*d*); *oe*, œsophagus; *ec*, ectoderm.
FIG. 13. *Anemonia sargassensis*, section through œsophagus, showing primary mesenteries and numerous secondary mesenterial buds; *d*, directive mesenteries; *ec*, ectoderm.



Fig. 2. *Sagartia luciae*
Oral view

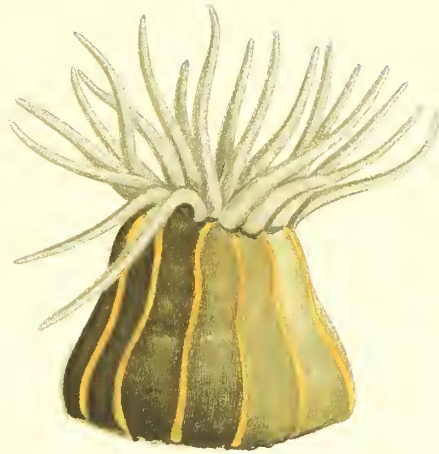


Fig. 1. *Sagartia luciae*
Side view



Fig. 3. *Anemonia sargassensis*



Fig. 4. *Eloatis producta*



Fig. 6.

Fig. 5. *Sagartia modesta*



FIG. 7.—*Sagartia modesta*.



FIG. 8.—*Cylista leucolena*.

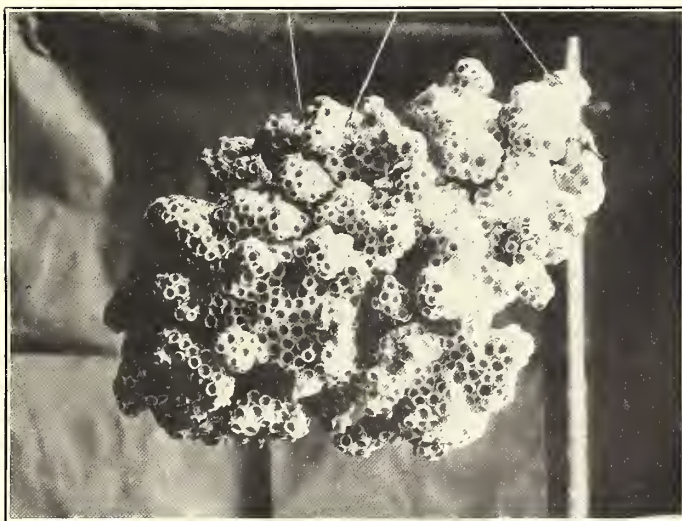


FIG. 9.—*Astrangia danae*.

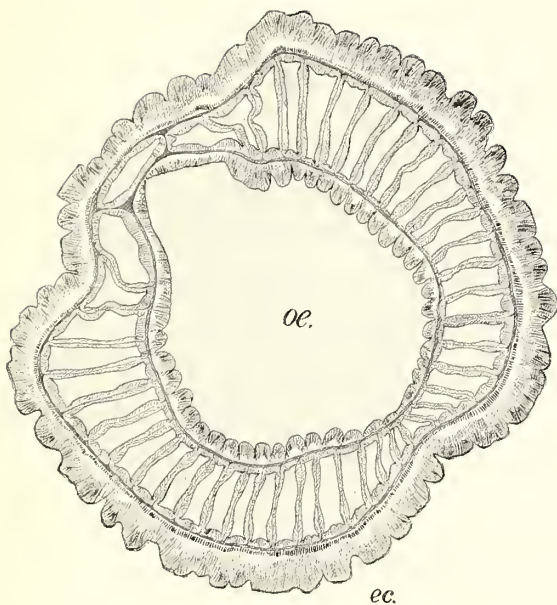


FIG. 10.—*Cerianthus americanus*.

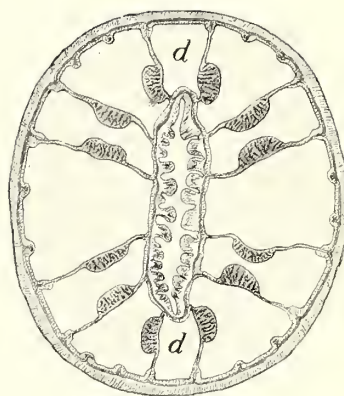


FIG. 11.—*Cylista leucolena*.

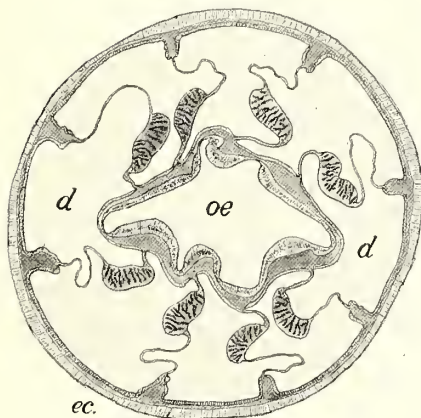


FIG. 12.—*Edwardsia elegans*.

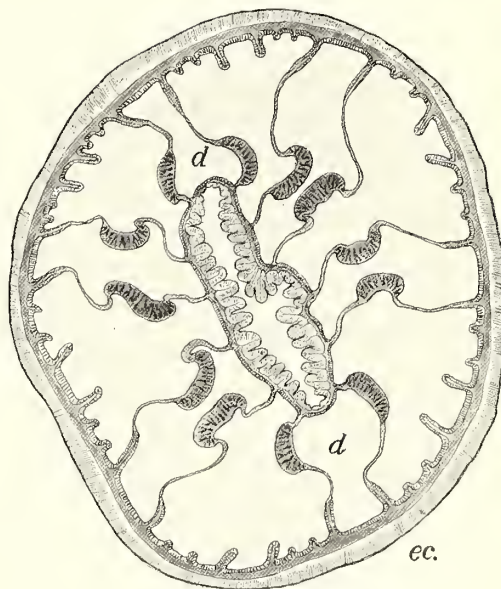


FIG. 13.—*Anemonia sargassensis*.

THE CEPHALOPODA OF THE HAWAIIAN ISLANDS

By S. Stillman Berry

THE CEPHALOPODA OF THE HAWAIIAN ISLANDS.

By S. STILLMAN BERRY,

INTRODUCTION.

The ensuing monograph was originally projected as a report on the collection of cephalopod mollusks taken by the United States Bureau of Fisheries steamer *Albatross* during her Hawaiian cruise of 1902. It was found, however, that the pages required to be only slightly amplified to become practically a monographic survey of the entire Hawaiian region, and this has accordingly been done. Wherever possible a full description is given from Hawaiian material of each species under consideration. This is succeeded by a brief discussion of the further range of the species, tables of dimensions, a short critical comparison with other nearly allied forms, and such other items as seemed relevant. In some cases, especially where a species has been known to the writer only through the descriptions of other authors, it has been thought well to reprint the diagnosis of the original author in full. The work was commenced at Stanford University in the autumn of 1908, and, with the exception of the season of 1909-10, was prosecuted more or less continuously in the zoological laboratories there from that time to November, 1912.^a

SOURCES OF MATERIAL.

The great bulk of the material upon which this report is based is the property of the United States Bureau of Fisheries and was obtained during the explorations of the United States Fisheries steamer *Albatross* on her extensive investigation in 1902 of the waters adjacent to the Hawaiian Islands, which constitute, zoologically speaking, what is known as the Hawaiian region. The principal part of the specimens have been turned over to the United States National Museum, but a set of the duplicates is deposited in the Stanford University collections.

I have further had for study the small series of shore forms already in the collections of Stanford University, most of them obtained by Dr. O. P. Jenkins during his visit to the islands in 1889, or by Dr. D. S. Jordan and Dr. B. W. Evermann in 1901. These

^a As on a former occasion, I must express my gratitude to Dr. Walter Kenrick Fisher, of Stanford University, for the kindly interest with which he has constantly followed the progress of this work in his laboratory. It is of interest to note, also, that Dr. Fisher was a member of the *Albatross* staff during the Hawaiian explorations, and the occasional color and habit notes which appear in his handwriting on the labels of some of the specimens are of more than ordinary interest, especially when we consider how few data of the sort are available for even the commoner species of this group of animals.

To Dr. Harold Heath I am once more under obligation for the opportunity to work up an important collection originally placed in his own hands for study. It is also due to him that the series of drawings prepared by Mr. R. L. Hudson came into my hands at the same time with the specimens, so that the major portion of them could be utilized in the present report. Other illustrations in these pages are the work of Miss Lora Woodhead, Mr. Henry Varnum Poor, and Mr. John Howard Paine, all of Stanford University.

collections include one species (*Onychoteuthis banksii*) which was not taken by the *Albatross*.

In addition to the above there have constantly been available the collections of cephalopods made by the *Albatross* during the Alaska salmon investigations of 1903 and the dredgings off the California coast in 1904, together with the considerable series of west American and Japanese specimens owned by Stanford University. Although all of these have already been made the subject of reports (Berry 1912a, 1912b), their value for comparative study in the present consideration has been inestimable.

The type specimens of new species together with certain others have already been assigned catalogue numbers by the authorities of the National Museum, and such numbers are carefully cited in the proper paragraphs of the following pages. In referring to the Stanford University material, I have for the sake of brevity adopted the University initials—L. S. J. U.—immediately succeeded by a catalogue number which has reference to the invertebrate series in the University collections.

As will be seen, the material thus utilized lacks only *Polypus hawaiiensis*, *Symplectoteuthis ovalaniensis*, and the clearly erroneous *Loligo gahi* and *Polypus fontanianus*, to embrace all the species known or reported from the islands, the great bulk of the records being nevertheless entirely new. The total number of specimens which I have personally examined is 210. These are distributed among 24 genera and include somewhat more than 29 species, only 4 of which have been previously recorded from the region. Some 15 of these species it has been found advisable to describe as new, and it is quite probable that several of the 10 or more forms represented by specimens too immature or too poorly preserved for accurate determination belong to species not yet described.

The *Albatross* collection has already formed the basis of two brief preliminary papers (Berry 1909, 1913), in which the majority of the new species were tersely described and in the first of which a provisional check list of all the species was also given.

HISTORICAL SURVEY.

With the exception of the two papers which have been just referred to as preliminary to the present report, no work specially devoted to Hawaiian Cephalopoda has ever been published. Even the scattered references contained in volumes of wider scope are not numerous and only to be found by dint of the most exhaustive searching. Despite its brevity, therefore, the following cursory survey of the literature is thought to be practically complete.

I have been unable to determine to what author belongs the honor of first bringing a Hawaiian member of our group to the public notice, since Gould in America and Souleyet in France both published in the same year. The latter author, reporting in 1852 on the mollusks taken during the voyage of the *Bonite*, describes only a single species from the islands, the *Octopus hawaiiensis*, a form which would naturally be expected to be abundant, but which has not been recognized with any certainty since.

In the magnificent memoir by Gould (1852) on the Mollusca of the Wilkes exploring expedition, two Hawaiian species are described for the first time, both of them common littoral forms, namely, *Octopus ornatus* Gould, and *Sepioteuthis archipinnis* Gould.

In 1879 Tryon published a monograph of the Cephalopoda as the first volume of his *Manual of Conchology*. In addition to the three species just noted, two other forms are accredited to our region, namely, *Loligo gahi* d'Orbigny and *Polypus fontanianus* d'Orbigny. Both of these, however, are characteristic South American types and the Hawaiian record in each case seems almost certainly to be an error.

The *Challenger* steamed through the very heart of the region and made a brief call at Honolulu, yet took but a single species of cephalopod. This was a common reef *Polypus*, three specimens of which reached England and were there described by Hoyle (1885) as *Octopus marmoratus*.

In 1899 Schauinsland reported the occurrence of the following species in the neighborhood of Laysan Island, his identifications being based on determinations by Dr. G. Pfeffer:^a

Octopus sp.	Ommastrephes oualaniensis.
Onychoteuthis Banksii.	Ommastrephes Sloanei.

In 1909 the present writer published preliminary diagnoses of seven supposedly new forms from the Hawaiian Islands, and as an appendix to the same paper added a simple check list of all the species known to occur in the region (Berry, 1909, p. 418). In this list some 22 species are named and 11 other forms are recorded without precise determination. This list, which follows herewith, should now be regarded as entirely supplanted by the present paper:

Cirrotheuthis (?) sp.	Semirossia (?) sp.
Argonauta böttgeri.	Stoloteuthis iris n. sp.
Argonauta (argo?).	Sepioteuthis arctipinnis.
Tremoctopus (near quoyanus).	Ommastrephes sagittata near sloanei.
Alloposus mollis.	Ommastrephid (young).
Bolitaena sp.	Onychoteuthis banksi.
Polypus hawaiiensis.	Symplectoteuthis oualaniensis.
Polypus hoylei n. sp.	Teleoteuthis appellofi.
Polypus ornatus.	Abralia astrosticta n. sp.
Polypus marmoratus.	Abralia sp.
Polypus α .	Abraliopsis sp.
Polypus β .	Pterygioteuthis giardi.
Polypus γ .	Tracheloteuthis riisei.
Scæurgus sp.	Chiroteuthis famelica n. sp.
Stephanoteuthis hawaiiensis n. gen. and sp.	Cranchia (Liocranchia) globula n. sp.
Euprymna morsei.	Cranchiid sp.
	Helicocranchia fisheri n. sp.

Three years later Naef (1912, p. 247) proposed the new genus *Iridoteuthis*, basing it upon the Hawaiian *Stoloteuthis iris* Berry as its type and single known representative.

^a Although fragmentary, Schauinsland's notes are of considerable interest, and in view of their inaccessibility to most students it may be worth while to repeat them here.

(P. 25) "... nicht selten hat man das Glück, hier auch einen der abenteuerlichen Tintenfische (Octopus) zu erbeuten, und zwar bisweilen in solcher Grösse, dass man sich vor seinen Saugarmen und scharfen Kiefern zu hüten hat."

(P. 92) "Neben den häufig bei Laysan sich findenden *Octopus*-Arten kommen dort an *Cephalopoden* (det. Pfeffer) noch vor: *Ommastrephes oualaniensis* Less. und *Omm. Sloanei* Gray, sowie *Onychoteuthis Banksii* Fér. Die drei letzten Arten bilden überwiegend die Nahrung der *Albatrosse*, wenigstens in der Zeit, in welcher sie ihre Jungen füttern. Die Exkremente derselben bestanden fast ausschliesslich aus Cephalopoden-Kiefern. Auch die *Sula*-Arten füttern anfangs ihren Nachwuchs mit verdauten Cephalopoden, später allerdings mit Fischen."

The same year a brief note was published by the writer (Berry, 1912b, p. 434) in which the Hawaiian *Ommastrephes* was awarded separate recognition as *O. hawaiiensis* n. sp. and a very brief definition given.

At about the same time (Berry, 1912c, p. 645) the identity of *Stephanoteuthis* with *Heteroteuthis* Gray 1849 having been recognized, the subsequent name was abandoned as a synonym (for this also see Naef, 1912, p. 246).

In 1913 the writer described the following new forms from the present material:

Laetmoteuthis lugubris n. gen. and sp.
Scæurgus patagiatus n. sp.
Euprymna scolopes n. sp.

Teleoteuthis compacta n. sp.
Abralia trigonura n. sp.
Pterygioteuthis microlampas n. sp.

In the present monograph all the species diagnosed in 1909 and 1913 are redescribed in better detail and figured throughout. Identifications corrected from the list of 1909, together with the few changes in nomenclature which have been found necessary since that time, will be made readily apparent by a glance at the following synopsis of the fauna. No additional new species are here described.

SYNOPSIS OF HAWAIIAN CEPHALOPODS.^a

ORDER DIBRANCHIATA OWEN.

SUBORDER OCTOPODA LEACH.

Family Cirroteuthidæ Keferstein.

Genus *Laetmoteuthis* Berry.

Laetmoteuthis lugubris Berry (2).

Family Argonautidæ (Cantraine).

Genus *Argonauta* Linné.

Argonauta böttgeri Maltzan (1+).

Argonauta sp. (1).

Genus *Tremoctopus* delle Chiaje.

Tremoctopus violaceus delle Chiaje (31).

Family Allopodidæ Verrill.

Genus *Alloposus* Verrill.

Alloposus mollis Verrill (1).

Family Bolitænidæ Chun.

Genus *Eledonella* Verrill.

Eledonella sp. (1)

Family Polypodidæ Hoyle.

Genus *Polypus* Schneider.

Polypus hawaiiensis (Souleyet) (o).

Polypus marmoratus (Hoyle) (13).

Polypus ornatus (Gould) (3).

Polypus hoylei Berry (4).

Polypus α (4).

Polypus β (15).

Polypus γ (4).

Polypus δ (1).

Polypus ε (2).

Genus *Scæurgus* Troschel.

Scæurgus patagiatus Berry (7).

^a The number of specimens of each species examined is given in parenthesis after the specific name.

ORDER DIBRANCHIATA OWEN—Continued.

SUBORDER DECAPODA LEACH.

Division Myopsida d'Orbigny.

Family Sepiolidae Keferstein.

Genus Euprymna Steenstrup.

Euprymna scolopes Berry (64).

Genus Stoloteuthis Verrill.

Stoloteuthis iris Berry (1).

Genus Heteroteuthis Gray.

Heteroteuthis hawaiiensis (Berry) (4).

Family Loliginidae (d'Orbigny).

Genus Sepioteuthis de Blainville.

Sepioteuthis arctipinnis Gould (4).

Division Ægopsida d'Orbigny.

Family Onychoteuthidae Gray.

Genus Onychoteuthis Lichtenstein.

Onychoteuthis banksii (Leach) (1).

Genus Teleoteuthis Verrill.

Teleoteuthis compacta Berry (1).

Family Enoploteuthidae Pfeffer.

Genus Abralia Gray.

Abralia astrosticta Berry (1).

Abralia trigonura Berry (1).

Genus Abraliopsis Joubin.

Abraliopsis sp. (1).

Genus Pterygioteuthis Fischer.

Pterygioteuthis microlampas Berry (2).

Family Histioteuthidae Verrill.

Histioteuthid, young (3).

Family Brachioteuthidae Pfeffer.

Genus Brachioteuthis Verrill.

Brachioteuthis riisei (Steenstrup) (8).

Family Ommastrephidae Gill.

Genus Ommastrephes d'Orbigny.

Ommastrephes hawaiiensis Berry (7).

Genus Symplectoteuthis Pfeffer.

Symplectoteuthis oualaniensis (Lesson) (o).

Genus Rhyncoteuthion Pfeffer.

Rhyncoteuthion α (11).

Rhyncoteuthion β (1).

Family Chiroteuthidae Gray.

Genus Mastigoteuthis Verrill.

Mastigoteuthis (?) famelica Berry (1).

Family Cranchiidae (Prosch).

Genus Liocranchia Pfeffer.

Liocranchia globulus Berry (3).

Genus Megalocranchia Pfeffer.

Megalocranchia fisheri (Berry) (1).

Genus Helicocranchia Massy.

Helicocranchia sp. (1).

CHARACTER AND RELATIONSHIPS OF THE HAWAIIAN FAUNA.

From the foregoing it will be seen that so far as is known the Hawaiian fauna includes about 25 named species of cephalopods, together with half as many more uncertain forms, some of which are doubtless worthy of recognition but which are only familiar to us by specimens either too young or too poorly preserved for a positive determination of the species. The total number of genera represented is 24, or about two-thirds as great as the total number of species. This is due to the fact that the genus *Polyopus* with 9 forms listed (at least 5 of them doubtful), *Argonauta* with 2 species, and *Abralia* with 2 species, are the only genera which appear more than once in the list. (Owing to various facts which are to be summarized on another page, *Rhyncoteuthion* should obviously be excluded from the present discussion.) The apportionment of the fauna among higher groups is conveniently shown in the following table:

TABLE I.

Divisions.	Number of genera represented.	Named species.	Unnamed or doubtful species.
Octopoda.....	7	9	7
Myopsida.....	4	4	0
Oegopsida.....	13	11	5
Total.....	24	24	12

One very striking feature which is brought out with particular emphasis in such a table is the surprising weakness of the myopsid element in the fauna. Of the four myopsid genera, one is *Sepioteuthis*, the remaining three are *Sepiolidæ*, and even of each of these but a single species has come to hand.^a The total absence of any representatives whatsoever of the great genera *Loligo* and *Sepia* in any of the collections was entirely unexpected. Of course Hawaiian species of one or both of these groups not improbably may yet come to light, but in any case I feel that the series of specimens collected by the *Albatross* is so representative that we may assert with confidence that neither genus attains any very great development in these waters, or even the prominence which we might reasonably expect when we consider what a dominant element they compose in the fauna of the Malaysian Archipelago as well as of Japan. *Loligo* especially is so abundant a genus and so cosmopolitan that it would be hazardous with our present knowledge to deny its occurrence anywhere. In the case of *Sepia*, however, it should be remembered that with the exception of a solitary and ill-authenticated record from the West Indies, not a single species is known from the waters adjacent to the American Continent nor indeed from the entire Western Hemisphere. The group being mainly a littoral one, we thus have *a priori* grounds for suggesting that wide oceanic areas may in some way form a special barrier to its dispersion. If this be true we should perhaps expect other littoral forms, such as the *Polypi*, to be distributed in accordance with the same principle; but this, as we shall see later, does not appear to be the case. An explanation of this anomaly may be found in the hypothesis that the dissemination of these other forms took place at a more ancient period. That the rise and dissemination of

^a It should be remembered, however, that to one of these species, *Euprymna scolopes*, belongs the distinction of being by far the most abundant Hawaiian cephalopod. Nearly one-third of the total number of specimens examined are referable here.

the *Sepiidae* actually is of comparatively recent occurrence receives distinct support from the circumstance that the dominion occupied by them is almost perfectly continuous and very symmetrically populated, with an extraordinarily rich development of species in the Indo-Malayan and Japanese regions, the apparent center of dispersion.

TABLE II.—DISTRIBUTION OF HAWAIIAN CEPHALOPODS.

Hawaiian species.	Bathymetric range.	Further distribution.	Bathymetric range.	Nearest analogue.	Distribution.	Bathymetric range.	Apparent degree of relationship.
<i>Lætmoteuthis lugubris</i> .	Fathoms, 258-284		Fathoms.	(?)		Fathoms.	
<i>Argonauta böttgeri</i> .	Surface.	Mauritius; Philippines; Australia.	Surface.	(?)			
<i>Argonauta</i> sp.	Surface.	(?)		<i>Argonauta argo</i> . <i>Argonauta pacifica</i> .	Mediterranean to Japan. Southern California to Galapagos Islands.	Surface. Surface.	(?) (?)
<i>Tremoctopus violaceus</i> .	Surface.	Eastern Mid-Pacific; Indo-Malayan; Japan; Mediterranean.	Surface.				
<i>Alloposus mollis</i> ...	286-290	North Atlantic.	197-715	<i>Alloposus pacificus</i> . (?)	Japan.....		Close.
<i>Polypus hawaiiensis</i> .	Shore.						
<i>Polypus marmoratus</i> .	Shore.	Ceylon, Rotuma, Amboina.	Shore.	<i>Polypus bimaculatus</i> .	Southern California to Panama.	Shore.	Fairly close.
<i>Polypus ornatus</i> ...	Shore.			<i>Polypus macropus</i> .	Mediterranean; Indian Ocean; Japan.	Shore.	Fairly close.
<i>Polypus hoylei</i>	257-460						
<i>Scaëurgus patagiatus</i> .	127-178			<i>Scaëurgus unicirrus</i> .	Mediterranean		Close.
<i>Euprymna scolopes</i> .	0-138			<i>Euprymna stenodactyla</i> .	Mauritius; South Pacific.	0-?	Very close.
<i>Stoloteuthis iris</i>	142-153			<i>Stoloteuthis leucoptera</i> ?	New England...	94-388	Not very close.
<i>Heteroteuthis hawaiiensis</i> .	385-733			<i>Heteroteuthis dispar</i> .	Mediterranean	500-700	Fairly close.
<i>Sepioteuthis arctipinnis</i> .	Shore.			<i>Sepioteuthis lessoniana</i> .	Red Sea to Japan and New Zealand.		Close.
<i>Onychoteuthis banksii</i> .	Surface.	Cosmopolitan	Surface.				
<i>Teleoteuthis compacta</i> .	385-733						
<i>Abralia astrosticta</i> ...	192-352			<i>Abralia steindachneri</i> .	Red Sea.....		Close.
<i>Abralia trigonura</i> ...	306-308			<i>Abralia andamanica</i> .	Bay of Bengal...	188-320	Close.
<i>Abraliopsis</i> sp.	Surface.	(?)		<i>Abraliopsis hoylei</i>	Mascarene Island; west coast Middle America.	1200-2200	Close.
<i>Pterygioteuthis microlampas</i> .	314-335			<i>Pterygioteuthis giardi</i> .	Morocco; Indian Ocean; west coast of middle America.	551-1250	Close.
<i>Brachioteuthis risei</i>	Surface.	Nearly cosmopolitan.	Surface.				
<i>Ommastrephes hawaiiensis</i> .	220-312			<i>Ommastrephes pacificus</i> .	Japan.....		Fairly close.
<i>Symplectoteuthis oualaniensis</i> .		Red Sea to Japan; Australia; Cocos Is.					
<i>Mastigoteuthis (?) famelica</i> .	385-733			<i>Chiroteuthis pelucida</i> ?	Bay of Bengal..	922	Fairly close (?)
<i>Liocranchia globulus</i>	Surface.			<i>Liocranchia reinhardtii</i> .	Atlantic; Indo-Malayan.	Surface.	Close.
<i>Megalocranchia fisheri</i> .	277-284			<i>Megalocranchia maxima</i> .	Cape of Good Hope.		Close.
<i>Helicocranchia</i> sp. ...	230-277	(?)		<i>Helicocranchia pfefferi</i> .	Ireland.....	350	Fairly close.

This brings us to a consideration of the relationships of the Hawaiian cephalopod fauna with that of other regions and an inquiry as to which of the great Pacific areas can be brought most closely into correlation with it. In Table II (p. 263) I have endeavored to present in compact form a summary of the more essential data to which we must look for an answer to the question. Although admittedly our knowledge is still little more than fragmentary, certain facts seem to be brought out with sufficient prominence to demand consideration. Of the 24 named species listed in the first column, it will be seen that 16, or about two-thirds and including all but one of the shore species, are unknown from any other region. Two others may be eliminated from the discussion as being practically cosmopolitan. Another (*Symplectoteuthis oualaniensis*) occurs very generally throughout the Indian and Pacific Oceans. Of the remainder four are inhabitants also of the Indo-Malayan region. One species is shared with the north Atlantic, but this one (*Alloposus mollis*) appears to be of oceanic habit, so that a wide distribution is in a way to be anticipated.

It is evident therefore that we must turn to the species which are peculiarly Hawaiian in order to gain any proper idea of the true elements which enter into the composition of the fauna. In one of the succeeding columns of the table I have accordingly listed the species which appear to be most closely allied to these, and in yet another column the regions where such analogues are known to occur. The parallel with the Indo-Malayan fauna here appears very striking and again, as in the latter region, a very respectable assemblage of species possesses decided Mediterranean affinities. Indeed one genus, *Scœurgus*, is now known for the first time outside the bounds of the Mediterranean, and, although the species from the two sources appear to be separately nameable, they are nevertheless surprisingly close. *Heteroteuthis hawaiiensis* is another species which finds its nearest ally no nearer than the Mediterranean and here again the relationship is close. The widespread stock of *Polyopus macropus*, which ranges in great abundance from the Mediterranean through the Red Sea, around southern Asia to the Malaysian Archipelago, and even to Japan, with practically no change in any of its characters throughout this entire area, also manages to reach the Hawaiian Islands, for it seems obvious that *P. ornatus*, though very distinct in itself, must have had its primary origin as an isolated outpost of this group. Of distinctly Indo-Malayan affinities, but not Mediterranean, are *Euprymna scolopes*, *Polyopus marmoratus*, *Abralia astrosticta* (apparently near to *A. steindachneri* of the Red Sea), and perhaps *Mastigoteuthis(?) famelica*. *Polyopus marmoratus* appears to be allied to the common *P. bimaculatus* of southern and Lower California, but aside from this somewhat anomalous example the fauna has little in common with that of western America.^a

With the Japanese fauna likewise, outside of the invading Indo-Malayan element shared by both, the Hawaiian cephalopods exhibit no particular relationship. *Ommastrephes hawaiiensis* is doubtless to be regarded as an offshoot of the same stock which gave

^a So little is at present known regarding the teuthology of the south Pacific that the Australian region has not here been considered as separate from the Indo-Malayan, although the reported presence of *Dosidicus gigas* in those waters would tend to show a certain relationship with the South American fauna.

origin to *O. pacificus* (and *sloanii* ?), and *Sepioteuthis arctipinnis* is similar or identical with *S. lessoniana*, but without exception all the species most truly characteristic of the one area are conspicuous only by their absence in the other. We are able to correlate at least a portion of the Japanese fauna with that of western North America much more successfully.

In summing up, then, it may be said that, although the ensemble of Hawaiian cephalopods shows many features peculiar to itself, it appears reasonable to regard it as an offshoot, now largely isolated, of the great Indo-Malayan fauna, and therefore impossible of any definite or satisfactory correlation with that of other regions of the north Pacific. That this statement is in substantial accord with the conclusions reached by students of other groups of animals is readily seen by a glance at almost any of the monographs dealing particularly with the fauna of the archipelago.

Nutting (Bulletin U. S. Fish Commission, vol. xxiii, for 1903, p. 934, 1906) in discussing the hydroids says that they "have unmistakable relationship with the Australian region," although (p. 935) "as would be expected from the isolated position of the Hawaiian Islands, the preponderance of peculiar species is very exceptionally large."

Miss Rathbun reaches similar conclusions from a study of the decapod crustaceans. She says that "the Hawaiian fauna is almost entirely Indo-Pacific, the islands forming the northeastern, as the Indian Ocean is the southwestern, limit for the majority of the species" (t. cit., p. 830, 1905). She finds but few species peculiar to the islands, however.

Fisher (t. cit., p. 999, 1906) finds the distribution of the starfishes indicative of entirely similar phenomena. He writes that "we are at once struck by the fact that the Hawaiian fauna bears more resemblance to that of the distant Indian region than it does to the fauna of America, notwithstanding that all the ocean currents which pass the Hawaiian Islands are coming from America and not from the west."

In the case of the shore fishes Jordan and Evermann (t. cit., p. 32, 1905) have found the fauna to be "frankly and entirely tropical, all the species belonging to genera characteristic of the tropical Pacific," but most of the species themselves seem to be peculiar to the islands.

The conclusions of Gilbert (t. cit., p. 578, 1905), after his critical examination of the deep-sea fishes collected by the *Albatross*, are especially full of interest: "An analysis of the list of species recorded in the present paper shows conclusively that the bathybial fishes of Hawaii, like those of its reefs and shores, have been derived as a whole from the west and south, and not from the east or north. In its entire facies, the fauna is strikingly unlike that of the Pacific coast of Mexico and Central America, and resembles strongly the assemblage of forms discovered by the *Albatross* and the *Challenger* off the coasts of Japan and the East Indies. Some of its members find their nearest known affines in the Bay of Bengal."

On the other hand, Mayer (t. cit., p. 1133, 1906) in his report on the Medusæ writes that "it appears the majority of the Hawaiian forms are of wide distribution," a conclusion entirely harmonious with what we know regarding such cephalopods as are of similar habit.

BATHYMETRICAL DISTRIBUTION.

The data accompanying the lists of specimens taken by the *Albatross* as given in this paper are partial extracts from the records of the voyage as given in the Report of the United States Fish Commission for 1902 (p. 397-432, Washington, 1903). For more full and detailed stational observations reference may be had to the original paper.

It is worthy of note that no truly abyssal forms were captured unless we so consider the two specimens of *Lætmoteuthis*, the mangled condition of which may perhaps be partly due to their having gotten considerably "out of their depth" when taken, as well as to rocks in the dredge. A glance at the table of stations given in the appendix of this report shows that the greatest depths from which any specimens of cephalopods were obtained were those sounded at stations 3989 (385-733 fathoms, *Heteroteuthis hawaiiensis*, *Teleoteuthis compacta*, *Mastigoteuthis*(?) *famelica*), 4039 (670-697 fathoms, *Eledonella* sp.), and 4110 (449-460 fathoms, *Polypus hoylei*). In no other instances was a member of the class obtained at a greater depth than 400 fathoms, and even in the cases above cited it seems by no means improbable that some of the actively nectonic species may have become ensnared in the dredge during its transit to the surface. Altogether it must be admitted that even the archibenthal regions have been scarcely drawn upon, and it is only concerning the reef and pelagic fauna that we can presume even a fair degree of knowledge. The two latter habitats have each their characteristic group of species, although certain of the smaller free-swimming forms are not uncommon in the reef pools, and both attain the richness customary in tropical regions. As is well known in the case of the fishes and other groups, many of the reef species are truly regal in their brilliantly variegated coloring and other ornamentation. *Polypus* entirely fulfills expectations in being the group most conspicuous on the reefs both in species and in number of individuals, but *Euprymna* and *Sepioteuthis* are also to be captured there. In the plankton we find the usual run of more delicate, less actively swimming forms—*Argonauta*, *Tremoctopus*, *Tracheloteuthis*, larval ommastrephids, histioteuthids, and octopods of various species and genera, *Liocranchia*, and the omnipresent *Euprymna*—nearly all warm-water species of wide dispersion.

As is shown in the table following, five species, mainly of very active habit, are found between the surface and the 100-fathom mark, the richest and by far the most varied fauna of all occurring in the deeper water down to a depth of 400 fathoms. The most remarkable bathymetric range exhibited by any single species is that of *Euprymna scolopes*, which, though very abundant at or near the surface, is frequently met with in all depths down to 130 or 140 fathoms and therefore appears in no less than four columns of the table. *Polypus hoylei* is recorded from 257 to 460 fathoms.

TABLE III.—BATHYMETRIC DISTRIBUTION OF HAWAIIAN CEPHALOPODS.

Shore.	Surface.	Surface to 100 fathoms.	100 to 500 fathoms.	Over 500 fathoms.
OCTOPODA. <i>Polypus hawaiiensis</i> . <i>Polypus marmoratus</i> . <i>Polypus ornatus</i> . <i>Polypus</i> γ. <i>Polypus</i> δ.	OCTOPODA. <i>Argonauta böttgeri</i> . <i>Tremoctopus violaceus</i> . <i>Polypus</i> α. <i>Polypus</i> β. <i>Polypus</i> γ.	OCTOPODA. <i>Polypus</i> ε.	OCTOPODA. <i>Laetmoteuthis lugubris</i> . <i>Alloposus mollis</i> . <i>Polypus hoylei</i> . <i>Polypus</i> ε. <i>Scæurgus patagiatus</i>	OCTOPODA. <i>Eledonella</i> sp.
DECAPODA. <i>Sepioteuthis arctipinnis</i> . <i>Euprymna scolopes</i> .	DECAPODA. <i>Euprymna scolopes</i> . <i>Onychoteuthis banksii</i> . <i>Abraliopsis</i> (young). <i>Histioteuthis</i> (young). <i>Brachioteuthis riisei</i> . <i>Rhyncoteuthion</i> α. <i>Rhyncoteuthion</i> β. <i>Liocranchia globulus</i> .	DECAPODA. <i>Euprymna scolopes</i> . <i>Onychoteuthis banksii</i> . <i>Ommastrephes hawaiiensis</i> . <i>Symplectoteuthis oualaniensis</i> .	DECAPODA. <i>Euprymna scolopes</i> . <i>Stoloteuthis iris</i> . <i>Heteroteuthis hawaiiensis</i> . <i>Teleoteuthis compacta</i> . <i>Abralia astrosticta</i> . <i>Abralia trigonura</i> . <i>Pterygioteuthis microlampas</i> . <i>Ommastrephes hawaiiensis</i> . <i>Mastigoteuthis</i> (?) <i>famellica</i> . <i>Megalocranchia fisheri</i> . <i>Helicocranchia</i> sp.	DECAPODA <i>Heteroteuthis hawaiiensis</i> (?) <i>Teleoteuthis compacta</i> (?) <i>Mastigoteuthis</i> (?) <i>famellica</i> (?)

COMPARATIVE ABUNDANCE.

The comparative abundance of the different species in the collection is readily appreciated by a glance at the figures appended to the synopsis on page 260. It is remarkable that out of a total of 210 specimens examined, 64, or nearly one-third, are *Euprymna scolopes*. Of the remainder, 31, or nearly one-sixth of the total, are *Tremoctopus violaceus*; 15 are the immature *Polypus* designated as β; 13 are *Polypus marmoratus*; eleven are the larval ommastrephids known as *Rhyncoteuthion*; 8 are *Brachioteuthis riisei*, while *Scæurgus patagiatus* and *Ommastrephes hawaiiensis* are represented by 7 specimens each.

The most notable catch of cephalopods made by the *Albatross* in any single haul was in the surface nets at station 3926, between Oahu and Laysan Islands, where 11 specimens representing 1 species each of no less than 5 genera were obtained.

LOCAL DISTRIBUTION.

Regarding the distribution and relative frequency of the littoral and shallow-water species among the respective islands of the archipelago, little or nothing can be said at the present time. As would be expected, most of the collecting has been done on Oahu in the neighborhood of Honolulu; a few specimens have occasionally come to hand from Maui, but almost nothing from the other islands. The remote islands of the Midway Group ought to prove particularly interesting in this respect, since their oceanic extent is large and we are completely ignorant concerning the cephalopods of their littoral fauna.

CLASSIFICATION AND NOMENCLATURE.

In conformity with my "Review of the Cephalopods of Western North America" (Berry, 1912a) I have followed the general lines of cephalopod classification laid down in the various works of Hoyle, with certain modifications adapted from Pfeffer's "Synopsis" (1900) and the masterly monograph of the *Valdivia* Ægopsida by Chun (1910). The present material has afforded few bizarre forms and, although highly important from a distributional and local standpoint, accomplishes very little toward the elucidation of the wider evolutionary problems. Of decided importance, however, is the discovery of an otherwise typical member of the family *Cirroteuthidae*, which is remarkable not only for being the second species in the entire group known to possess an odontophore, but also for its apparently total lack of the alternating rows of cirri along the arms, hitherto thought to be a characteristic as invariable as it is puzzling. The occurrence of a Pacific *Scæurgus* and a new sepiolid having affinity with the Atlantic *Stoloteuthis leucoptera* is also noteworthy. The presence in the collection of a large series of young ommastrephids comprising at least two *Rhyncoteuthion*-like forms specifically distinct from one another indicates that the occurrence of the curious *Rhyncoteuthion* stage is an exceedingly widespread ontogenetic character in this family and one by no means confined to the typical genus.

The primary division of the Dibranchiata of Owen into the Octopoda (devilfishes) and Decapoda (squids^a), as proposed by Leach in 1817, is here adhered to, although the latter term is very confusing in view of the prior use of the name for a well-known group of Crustacea (Decapoda Latreille 1806). In many respects the restoration of Blainville's Octocera and Decacera would be much more satisfactory, an excuse for discarding the complementary term Octopoda being possibly available because of the existence of Octopodia Schneider 1784, which was proposed as a general term for the entire class over a decade before Cuvier called them Cephalopoda.

I have found myself quite unable to accept the various major divisions into which some authors have grouped the Octopoda, but on the other hand I have been unable to formulate any more natural arrangement of my own which could be utilized in their stead. In regard to the Decapoda, however, the anciently recognized bifurcation into Myopsid and Ægopsid forms seems very convenient and on the whole a natural separation. Chun's further division of the latter group into Ægopsida libera and Ægopsida consuta appears to me cumbersome and but little superior to the nearly or quite synonymous Teuthidea and Taonidea of Verrill. For the purposes of the present paper it is not, however, necessary to adopt either system.

In the arrangement of the families themselves scarcely any two authors are in entire agreement, so that the sequence herein followed can be regarded as in no way more than provisional.

A word should be said in regard to the sort of morphological characters chiefly depended upon by the author in distinguishing species; that is, beyond such conspicuous differences in bodily structure and general form as obviously require no explanation

^a In the Hawaiian Islands the term "squid" is colloquially employed to include nearly all cephalopods, especially the edible forms such as *Polypus*, even though the usage is not scientific nor accurate English.

or apology even to the layman. This is particularly needful concerning the Octopoda, as in this group it is often very difficult to lay down on paper a hard and fast line respecting a given character which will invariably serve to separate a species from some other perhaps very closely allied. Here, in the absence of direct comparison between specimens, a sort of average of the entire physiognomy is largely depended upon, taking into consideration the relative length of the arms, the shape and extent of the umbrella, the presence or absence of ornamental processes of various sorts upon the integument, and the more evident conditions of preservation, which frequently affect the features already stated to a degree which can scarcely be too strongly emphasized. When the specimens are males, however, the structure of the hectocotylized arm is variously modified, usually constant in its peculiarities, and hence a criterion of the highest importance; perhaps no other single feature so well maintains its value in preserved material. I am also inclined to treat with respect any decided peculiarities of color, particularly when the various pigments appear to be disposed after the manner of a definite pattern. Frequently the so-called "funnel organ" exhibits tangible modifications in shape, though whether these latter are more valuable than confusing as a key to interrelationship is not yet apparent.

Among the Decapoda some of the above-mentioned features are of very minor specific significance. Here I have frequently given considerable weight to relatively minute differences in the form and arrangement of the suckers (or hooks) on the sessile arms and more particularly, on the terminal clubs of the tentacles, as these characters, even though small, are definitely to be apprehended and usually little affected by the action of the preserving medium. Nevertheless, there is certainly need for a greater quantity of comparative data showing the range of variation in these organs and until this is available there is constant danger that too much emphasis has been placed upon their details. Among the luminous forms, particularly the *Ægopsida*, the arrangement and structure of the photogenic organs is nearly always subject to important modification, both specific and generic or even of higher significance. The funnel organ appears to be of less practical systematic value in the Decapoda than in the Octopoda, for although it undergoes considerable modification among different genera (particularly the various *Cranchiidæ*), the differences between those of closely allied species are apt to be too slight to be appreciable.

On account of their easy preservation as "hard parts," the gladius and radula have occupied a dominant position in the schemes of classification of many of the older authors as well as a few of the more recent ones, but the undesirable mutilation of the specimen entailed by their examination, coupled with the writer's belief that their relative importance has been greatly overrated, has in the present work prevented their receiving the attention to which they are perhaps more justly entitled. Other "hard parts" which are oftentimes very useful to observe are the horny rings which arm the apertures of the suckers in most if not all Decapoda and which often show interesting modifications, chiefly depending upon the varying degrees of smoothness or denticulation of their outer margins.

Wherever a specimen appeared to possess definable characters of its own, however minute, the present writer has ranked himself frankly with the "splitters," especially in cases where the nearest known ally of such a form has been described from a far distant region. This procedure has not been resorted to from any desire to describe "new species," but because of a conviction that wherever a given animal from a definite locality can be referred to a previously named species only with considerable doubt, the exigencies of systematic zoology are much better to be subserved by the provisional use of a separate name. To many a student of geographical distribution the possible evil of one more synonym does not seem nearly so repugnant as the improper listing of a species, through imperfect or incorrect knowledge of its totality of characters, from a region where it does not (often even remotely) belong.

In matters of taxonomy the writer has unreservedly sought strict literal obedience to the published rules of the International Commission for Zoological Nomenclature. Thanks to the careful work of previous authors, notably Hoyle, this procedure has not resulted in the demolition of very many teuthologic landmarks. It is possible that additional changes ought in some instances to be made, but wherever any given case did not clearly appear to be governed by some definite rule in the code, the current prevailing usage was adhered to.

It might be well to call attention to the fact that in the verbal orientation of specimens for purposes of description, the terms anterior and posterior, dorsal and ventral have been used in their usual physiological sense (i. e., with relation to the normal activities of the adult animal) rather than in their strict morphological (and embryological) significance, which latter would necessarily result in a more complete reformation of the current anatomical nomenclature than could well be attempted at the present time. It must be admitted, however, that to the student of molluscan comparative anatomy recourse to a system of topographic names based on the latter system would have much to commend it.

ECONOMIC IMPORTANCE.

In the Hawaiian Islands, as in most other maritime countries, the common littoral cephalopods form a very important source of food. Both *Polyopus* (particularly *P. marmoratus* and *ornatus*, to judge from the market specimens before me) and *Sepioteuthis* are frequently offered for sale in the Honolulu markets. The Hawaiian word denoting the *Polyopus*, and perhaps other forms as well, is "hee." Cobb (1905, pp. 734, 736, 740) gives the following interesting account of some of the various modes of procedure resorted to by the natives for their capture:

Spears are frequently used in fishing for the hee (octopus), principally by women. This animal generally makes its home in small circular holes in the rocks on the reefs. When the fisherwoman finds a hole that she thinks is occupied she runs the spear into it gently. Should a hee be there it comes out to see what is the matter, the spear is run through it, and it is brought to the surface. The woman usually carries a smaller spear also, and with this she pricks or hits the animal in the head until it is stunned or killed, otherwise it might twine around her arms or legs and cause serious difficulty.

* * * * *

In fishing for hee (octopus) the native dives to the bottom, and, with a stick, pokes around in the small holes in which the animal lives. When he touches one it seizes the stick and allows him to draw it out of the hole. On reaching the surface the native seizes his captive with his hands and bites into its head, thus killing it.

* * * * *

The native is a great lover of the hee and has a number of methods of capturing it, one of the most interesting of which is with the cowrie shell. One or more cowrie shells of the Mauritiana or Tiger varieties are attached to a string. When only one is used, an oblong pebble about the size of the shell is tied to the face of it, a hole is pierced in one end of the back of the shell, a line is passed through, and after being fastened here, allowed to hang a few inches below the shell, to which a hook, whose point stands almost perpendicular to the shaft or shank, is attached. Only shells with small red spots breaking through a reddish-brown ground have an attraction for the hee, and it will not rise to any other kind. Shells which have suitable spots but unsuitable background are given the desired hue by steaming them over a fire of sugar-cane husks.

On arriving at the fishing ground the fisherman in pursuit of hee either chews up and spits upon the water a mouthful of candlenut meat, to render the surface glassy and clear, or he uses the water glass, which is described below. He drops the shell into the water, and by means of the line swings it back and forth over a place likely to be occupied by a hee. The greedy animal perceives the shell, shoots out an arm, and seizes it. If the bait is attractive, after a few moments' hesitation another arm is placed around it, and then another, until at last the animal withdraws itself entirely from its hole and hugs the shell closely to its body, oblivious of everything else. The fisherman then draws it rapidly up through the water, and when it raises its head at the surface, pulls it over against the edge of the canoe and delivers a blow between the eyes with a club which is generally fatal. Owing to the hee's quickness with its eight tentacles or arms, the fisherman has to be very rapid in his movements, as the animal would be no mean antagonist should it have an opportunity to seize him with its arms. The natives say that a number of persons have lost their lives in struggles with the octopus. This method of fishing is called by the natives "Lawaia hee me ke lcho" (squid catching with cowrie).

Nearly all squids and a good many octopods possess a further economic value in that they comprise one of the chief articles of diet for such birds as the albatross and shearwater, as well as for many of the more important food fishes.

KEY TO THE CEPHALOPODA KNOWN TO INHABIT THE HAWAIIAN ISLANDS AND ADJACENT WATERS.

I. Arms normally eight in number, tentacles being absent; suckers sessile, without a horny ring (OCTOPODA).

1. A pair of lateral oar-shaped fins present; suckers in a single row. (Family Cirroteuthidæ.)

2. Radula present; suckers not flanked by paired cirri. *Latmoteuthis lugubris*, p. 275.

1'. No fins.

3. Hectocotylized arm of male involving the entire third arm of one side, developed in a specialized sac, and separable at maturity; animals pelagic. (Family Argonautidæ.)

4. Dorsal arms of female with terminal winglike expansions modified for the secretion of an external "shell;" left third arm of male hectocotylized; no aquiferous pores present on head. (Genus *Argonauta*.)

5. Shell relatively small, compactly coiled, without auricular expansions at sides.

Argonauta böttgeri, p. 277.

5'. Shell large, more or less auriculate at the sides. *Argonauta* sp., p. 280.

- 4'. Dorsal arms of female connected by a broad velum, but without terminal expansions; no external shell; right third arm of male hectocotylized; aquiferous pores present on head. *Tremoctopus violaceus*, p. 281.
- 3'. No aquiferous pores; no external shell; dorsal arms normal.
6. Body soft and gelatinous; suckers in two rows; hectocotylus of male involving entire right third arm, which is presumably separable. *Alloposus mollis*, p. 287.
- 6'. Body soft; suckers in a single row; hectocotylized arm not separable (family *Bolitaenidae*). *Eledonella* sp., p. 289.
- 6''. Body comparatively firm; suckers in two rows; hectocotylus of male confined to tip of one third arm, to which it forms a spoon-shaped extremity. (Family Polypodidae.)
7. Hectocotylus affecting third arm of right side. (Genus *Polypus*).
8. A conspicuous pigmented oculation obliquely in front of each eye; hectocotylus minute. *Polypus marmoratus*, p. 291.
- 8'. No definite ocular markings in front of the eyes.
9. Adult brightly colored, the pigment conspicuously arranged in longitudinal bands or series of spots; arms very long and attenuate. . . *Polypus ornatus*, p. 294.
- 9'. No definitely arranged color pattern.
10. Body smooth, without cirri; second arm pair longest; color dark. *Polypus hawaiiensis*, p. 290.
- 10'. Body finely papillose, rather soft, with blunt cirri over the eyes; mantle opening small; color uniformly pale. *Polypus hoylei*, p. 296.
- 7'. Hectocotylus affecting third arm of left side; body bounded by a conspicuous peripheral fold. *Scæurgus patagiatus*, p. 305.
- II. Arms normally 10 in number, one pair being greatly modified to form the "tentacles"; suckers distinctly pedunculate, their apertures usually bounded by a chitinous ring (DECAPODA).
1. Eyes covered by a continuous membrane (division Myopsida).
2. Adult small; body short, rounded posteriorly, with round or ovate lateral fins; gladius much reduced or wanting. (Family Sepiolidae.)
3. Dorsal margin of mantle fused with head in nuchal region.
4. Fins of moderate size; suckers in four rows on the arms and 16 or more on the tentacle club; left dorsal arm hectocotylized. *Euprymna scolopes*, p. 312.
- 4'. Fins very broad and longer than the mantle; suckers on the arms in two rows; a conspicuous shield-shaped patch on the ventral surface of the mantle. *Stoloteuthis iris*, p. 316.
- 3'. Dorsal margin of mantle free; funnel covered by a conspicuous forward prolongation of the mantle. *Heteroteuthis hawaiiensis*, p. 319.
- 2'. Adult relatively large; body elongate, pointed posteriorly; fins marginal, extending the entire length of the mantle; gladius well developed, its texture horny throughout. *Sepioteuthis arctipinnis*, p. 308.
- 1'. Eyes with a perforated lid (division Ægopsida).
5. Part of the suckers with their chitinous rings transformed to hooks.
6. Sessile arms with true suckers only; one or more rows of hooks on tentacle club.
7. Adult moderately large; two rows of hooks on the tentacle club. *Onychoteuthis banksii*, p. 322.
- 7'. Adult small; hooks and suckers of tentacle club in four rows. *Teleoteuthis compacta*, p. 324.
- 6'. Sessile arms with part of the suckers modified into hooks. (Family Enopteuthidae.)
8. All suckers of sessile arms modified into hooks except at the extremity; hooks also present on tentacle club; ventral surface of mantle ornamented with numerous photogenic organs.
9. Buccal membrane pale in color; tips of ventral arms normal.
10. Photophores of mantle distinctly of two types and showing a definite bilateral arrangement; fins comparatively small. *Abrolia astrodicta*, p. 326.

- 10'. Photophores not conspicuously differentiated into two main types; their bilateral arrangement obscure; fins half as long as the mantle.
Abrolia trigonura, p. 329.
- 9'. Buccal membrane dark reddish or violet in color; ventral arms with a series of three conspicuous heavily pigmented beadlike organs at their tips.
Abroliaopsis sp., p. 331.
- 8'. Tentacle club with suckers only, but few hooks on sessile arms; numerous photogenic organs on the eyeball and within the pallial cavity, but none on the outer aspect of the mantle.....*Pterygioteuthis microlampas*, p. 332.
- 5'. None of the suckers with their chitinous rings transformed to hooks.
11. Mantle free all round anteriorly (not true of *Symplectoteuthis*, as see below).
12. Numerous photogenic organs on the body, head, and arms. (Family Histiotenuthidæ), p. 335.
- 12'. Photogenic organs few in number or absent.
13. Funnel articulating with the mantle by a ⊥-shaped groove. (Family Ommastrephidæ.)
14. Sucker bearing portion of tentacles greater than half the total length; fixing apparatus poorly developed. *Ommastrephes hawaiiensis*, p. 338.
- 14'. Sucker bearing portion of tentacles less than half the total length.
15. Mantle fused with the funnel on at least one side; fixing apparatus a distinct carpal group of pads and suckers.
Symplectoteuthis oualaniensis, p. 341.
- 15'. Animal small; clubs of tentacles fused to form an X-shaped or proboscis-like organ....."*Rhyncoteuthion*", p. 341.
- 13'. Funnel articulating with the mantle by a simple pit or groove.
16. Mantle delicate, membranous, transparent; fins sagittate; pelagic.....*Brachiotenuthis riisei*, p. 336.
- 16'. Mantle fleshy, produced to a delicate point posteriorly; fins lanceolate, over half as long as the mantle; ventral arms much the longest.....*Mastigoteuthis* (?) *famelica*, p. 344.
- 11'. Mantle fused with the funnel on either side and with the head in the nuchal region; mantle ample, thin, transparent; viscera confined to a very small proportion of the pallial cavity. (Family Cranchiidæ).
17. Mantle ornamented with several series of cartilaginous tubercles; mantle greatly inflated. *Liocranchia globulus*, p. 346.
- 17'. Mantle smooth; only moderately inflated.
18. Eyes enormous, rounded, sessile. *Megalocranchia fisheri*, p. 348.
- 18'. Eyes much smaller, oval, upon short stalks.
Helicocranchia sp., p. 350.

NOTE.—Except in the case of one or two well-known and widely distributed species, it has been my endeavor in the following pages to make the list of references preceding the description of each species as nearly complete as possible, and it is hoped that the occasional parenthesized comments regarding the nature of particular citations will prevent the confusion which might otherwise accrue through the promiscuous cataloguing of trivial and important references in the same tables. An attempt has been made to economize the time of the reader by printing all citations of special present importance in bolder type than the remainder.

Phylum MOLLUSCA.

Class CEPHALOPODA Cuvier 1798.

- Octopodia* Schneider 1784, p. 108.
Cephalopoda Cuvier 1798 (*vide* Gray).
Cephalopodia Rafinesque 1815, p. 139 (*vide* Binney and Tryon, p. 14).
Cephalophora de Blainville 1825, p. 364.

Order DIBRANCHIATA Owen 1836.^a

Antepedia Rafinesque 1815, p. 139 (*vide* Binney and Tryon, p. 14).

Cryptodibranchiata de Blainville 1824, p. 172 (*vide* Verrill).

Acetabulifères d'Orbigny 1835, p. 1.

Dibranchiata Owen 1836, p. 127.

Acetabulifera d'Orbigny 1845, p. 157.

Antepedia Gray 1849, p. 2.

Dibranchia Pelseneer 1906, p. 336.

Arms eight or (inclusive of the tentacles when present) ten in number; furnished with longitudinal rows of acetabulæ or suckers along their inner surfaces. Funnel a closed tube. Normally but a single pair each of ctenidia and renal organs present. Visceral mass naked; shell much reduced and embedded in the tissues of the mantle, frequently absent. Eyes highly developed and with closed cavities; a crystalline lens present. Characteristic and intricately constructed dermal pigment cells called "chromatophores" are developed in the integument.

This order includes all living cephalopods except *Nautilus*.

Suborder OCTOPODA Leach 1817.

Octopia + *Argonautea* Rafinesque 1815, p. 139 (*vide* Binney and Tryon, p. 14).

Octopoda Leach 1817, *vide* Gray.

Octocera de Blainville 1824 (*vide* Verrill); 1825, p. 365.

Octopoda d'Orbigny 1845, p. 163.

Octopia Gray 1849, p. 2, 3.

Octopoda Verrill 1881, p. 360.

Arms normally always eight in number and similar (with the exception of the hectocotylized arm in the male); tentacles absent. Suckers sessile, usually with thickened bases; their apertures not equipped with horny or chitinous rings. Body usually short; always rounded posteriorly; finless, or rarely with one or two pairs of weak oar-shaped lateral fins. Head and mantle broadly continuous in the nuchal region. Cœlom greatly reduced. No gladius. Wherever hectocotylization occurs it is one arm of the third pair which is affected. With the exception of the recently described *Melanoteuthis* Joubin 1912, specialized photogenic organs are unknown in the entire suborder.

Family CIRROTEUTHIDÆ Kieferstein 1866 em.

Pteroti Reinhardt and Prosch 1847, p. 38.

Cirroteuthidæ Kieferstein 1866, p. 1447.

Cirroteuthidæ Verrill 1881, p. 382.

Cirroteuthidæ Hoyle 1904, p. 3.

Adult animals commonly of large size. Body equipped with one or sometimes two pairs of lateral oar-shaped fins. A well-developed internal skeleton, comprising a broad saddle-shaped or horseshoe-shaped dorsal cartilage and a few lesser elements. Suckers in a single row which usually alternate with two flanking rows of paired cirri. Radula usually absent.

Genus LÆTMOTEUTHIS Berry 1913.

Lætmoteuthis Berry 1913, p. 563.

Adult of large size. Body rounded, with a small, weakly supported, transversely elongate fin attached to either side of the mantle. Arms moderately long; connected for the greater part of their length by an ample umbrella; intermediate web lacking. Suckers large, little elevated, in a single slightly zigzag row; paired cirri absent, or at best greatly reduced (possibly confined to the tips of the arms). Radula neither wanting nor reduced, but generously developed and with seven rows of teeth.

^a Date often given as 1832, but the paper upon which such quotation is based is unknown to me.

Type.—*Lætmoteuthis lugubris* Berry 1913, a species of the Hawaiian Islands.

The genus is closely allied to both *Cirroteuthis* and *Stauroteuthis*, but differs in the absence of paired cirri and the presence of an odontophore.

Lætmoteuthis lugubris Berry 1913. (Pl. XLIX, fig. 1, 2.)

Cirroteuthis (?) sp. Berry 1909, p. 418 (mere record).

Lætmoteuthis lugubris Berry 1913, p. 563.

Body large, rounded posteriorly. Lateral fins situated well back on the mantle, but small, transversely elongate, their greatest dimension (width) about twice as great as their length (fig. 2). Funnel thin walled, very large and broad; interior ample. Eyes probably large.

Arms long, appearing merely as thickenings or soft folds in the broad and ample umbrella and without any intermediate web connecting them thereto. Umbrella longest between the ventral arms, but everywhere extensive though very thin. Suckers large, flattened, distant; in a single series, though frequently somewhat zigzag; slightly, but not much, firmer in texture than the arms or umbrella; round-tubercular in shape; the apertures contracted, their margins crenulate. Paired cirri indistinguishable.

Mandibles large, compressed; but, with the exception of the sharp powerful beaks, thin and comparatively fragile; color black, horny at margin. (Pl. XLIX, fig. 1, 2.)

A very large and perfectly developed radula present; of the seven rows of teeth the tricuspid medians are considerably the largest.

Surface color a livid dark brownish slate, with a somewhat bluish cast over the inner surface of the umbrella in preserved specimens.

The label accompanying the type contains a note to the effect that the color of the specimen when captured was chocolate brown. Chromatophores small, numerous, and heavily distributed over the entire surface.

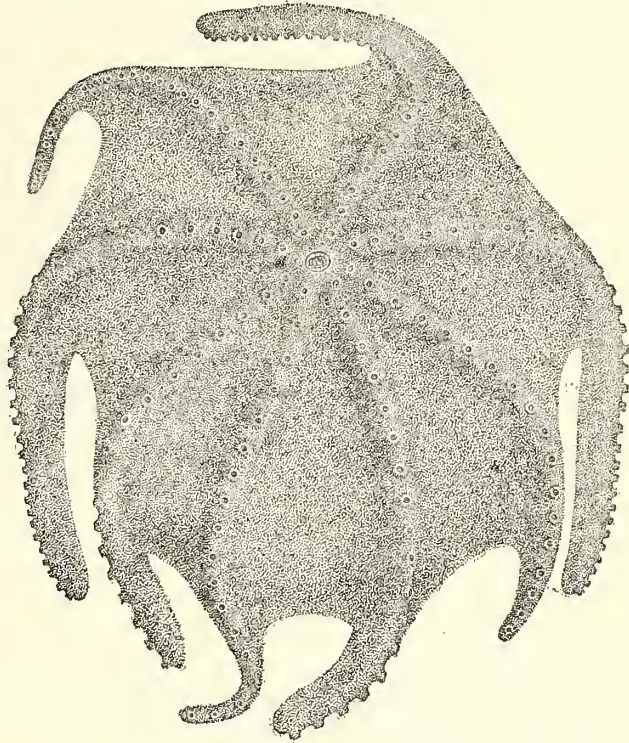


FIG. 1.—*Lætmoteuthis lugubris*, intraumbrellar aspect of type, considerably restored [211], $\times \frac{1}{6}$. Drawn by R. L. Hudson.

MEASUREMENTS OF *LÆTMOTEUTHIS LUGUBRIS*.

	Measure- ment.	Number of suckers.		Measure- ment.	Number of suckers.
Length of—	mm.		Length of—	mm.	
Right dorsal arm.....	430+	18+	Left ventral arm.....	110+	5+
Left dorsal arm.....	400+	16+	Umbrella between dorsal arms.....	300	
Right second arm.....	260+	8+	Umbrella between ventral arms.....	100	
Left second arm.....	430+	18+	Funnel.....	72	
Right third arm.....	350+	23+	Diameter of one of largest suckers.....	9	
Left third arm.....	210+	10+	Length of extracted radula.....	22	
Right ventral arm.....	330+	29+	Width of toothed portion of radula.....	8	

Type.—Catalogue No. 214385, United States National Museum. [S. S. B. No. 211.]

Type locality.—Albatross station 3904, surface, off Mokapu Islet, north coast of Molokai, Hawaiian Islands; one fragmentary specimen, April 30, 1902.

Distribution.—Vicinity of Molokai, Hawaiian Islands (*Albatross*).

Specimens examined.—In addition to the type but one other even more fragmentary specimen has been seen. This was taken in the Pailolo Channel near Molokai, from a depth of 258 to 284 fathoms, Albatross station 3898 [S. S. B. No. 212].

Remarks.—Both the specimens mentioned are in extremely fragmentary and indeed partially decomposed condition. In the larger example, which has been chosen for the type, only the mouth parts, fortunately together with a large part of the umbrella and the inclosed portions of the arms, remain in a recognizable state. The tips of the arms are missing, and the viscera as well as the eyes have been entirely torn from the body. What remains of the head and mantle is tangled and lacerated beyond repair. The lateral fins still adhere and are fortunately more or less intact. The funnel is present, but there is no trace of the funnel organ. Large fragments of the internal cartilages remain but defy any accurate description at my hands.

The smaller specimen is even more mutilated, so that here only the buccal mass and those portions of the umbrella and arms which immediately adjoin it are left to us.

Even from these wrecks, however, enough has been made out to render it evident that a species is represented which, though closely allied to *Cirroteuthis* and *Stauroteuthis*, differs very markedly in the apparently total absence of cirri on any of the arms as well as the presence of an odontophore, a structure reported to exist in no species of the two genera named except the recently described *C. macrope* Berry from the coast of California. Perhaps, indeed, it is not impossible that the latter species is congeneric.

In addition to the supposed absence of cirri, this species is distinguishable from *Cirroteuthis magna* Hoyle, *C. umbellata*

Fischer, *C. megaptera* Verrill, *C. mülleri* Eschricht, and *Stauroteuthis meangensis* Hoyle, by the relatively smaller and differently shaped fins, which are obovate and in outline more nearly like those of *C. pacifica* Hoyle. From the last species, however, the present form differs in the larger, much less numerous suckers,^a lack of cirri, and less prominent differentiation of the arms from the web. It differs, moreover, from *C. magna*, *C. mülleri*, and *S. syrtensis* Verrill in the lack of an "intermediate web" joining the arms to the umbrella. Correlation of the *Albatross* specimens with the descriptions of *C. caudani* Joubin, *C. plena* Verrill, *C. macrope* Berry, *C. grimaldii* Joubin, or *S. hippocrepium* Hoyle is equally out of the question. The tendency to a zigzag displacement exhibited by many of the suckers might be regarded as a characteristic feature, were it not for the possibility that it is due to distortion. All the basal suckers are relatively very distant from one another, the space between those of the same row being about 25 millimeters, but they gradually become more closely ranked distally.

Of course the possibility must not be overlooked that the apparent absence of cirri may be due to their restriction to the extremities of the arms as above suggested, but to the unfortunate state of preservation of the material. However, the appearance of the specimens in question is such that I have felt obliged to regard the possibility as a remote one, so that the erection of a new group seems expedient.

It is extremely unfortunate that the condition of both specimens is so unsatisfactory, but they belong to a family of abyssal octopods of such elusive habit and tender structure that almost all the described species have been founded upon similar fragmentary material. We have a really complete knowledge of scarcely any of these forms, and it may be that the number of nominal species will have

^a An appearance which perhaps may be partially due to the loss of the distal portions of the arms, as in quite a number of forms the basal suckers are less crowded than their successors.



FIG. 2.—*Latmoteuthis lugubris*, dorsal aspect of left fin of type [211], natural size. Drawn by R. L. Hudson.

to suffer a certain reduction when better methods, better appliances, and more extensive researches have further enriched our museums, but for the present there seems no way of dealing with them except to carefully describe each apparently divergent specimen as it comes in.

The dimensions attained by *L. lugubris* should often be considerable, as when living the larger of the specimens in hand must have had a total arm spread of over 80 centimeters.

Although neither of the Hawaiian specimens was actually obtained from an abyssal depth, there is every reason to believe that such was in reality their place of origin.

Family ARGONAUTIDÆ (Cantraine 1840) Gray 1847.

Argonautides Cantraine 1840, p. 20.

Philonexidæ d'Orbigny 1845, p. 199.

Ocythoia Gray 1847, p. 204.

Ocythoidæ (Argonautidæ?) Gray 1849, p. 3, 28. + *Philonexidæ* Gray, op. cit., p. 3, 29.

Argonautidæ H. and A. Adams 1853, vol. 1, p. 23.

Argonautidæ (pars) Naef 1912b, p. 197, 198.

Octopods of small to moderate size and pelagic habit. Body rounded or slightly elongate; without fins. Sexes conspicuously dimorphic. Males much smaller than the females; hectocotylization affecting one of the ventro-lateral arms, which, having its origin in a specialized sac, becomes developed into a highly modified and detachable copulatory organ, which persists separately for a certain length of time in the mantle cavity of the female. Suckers in two rows on all the arms.

Subfamily ARGONAUTINÆ s. s.

Third right arm of male hectocotylized; outer aspect of hectocotylus smooth. Dorsal arms of female furnished with broadly expanded glandular membranes at their extremities, which serve to secrete and hold in embrace a delicate involute calcareous shell, which latter functions as an ovarium as well as a partial retreat for the animal itself. Articulation between mantle and funnel cartilaginous. Funnel organ comprising a Λ -shaped dorsal cushion and a pair of ventro-lateral pads.

Genus ARGONAUTA Linné 1758.

Argonauta Linné 1758, p. 708.

Nautilus Schneider 1784, p. 120 (not of Linné 1758).

Ocythoe Leach 1817, p. 295 (not of Rafinesque 1814).

Hectocotylus (pars) Cuvier 1829, p. 147.

Todarus Rafinesque 1840, p. 64 (*fide* Binney and Tryon, p. 94).

Argonauta d'Orbigny 1845, p. 210.

For the characters of this genus see above under the subfamily, of which this is the only known group. Here are included the familiar argonauts or "paper nautili." At least two species are inhabitants of the Hawaiian region.

Type.—*Argonauta* Argo Linné 1758 (the species first mentioned), a characteristic Mediterranean type.

Argonauta bottgeri Maltzan 1881. (Pl. XLVIII, fig. 5.)

Argonauta Bottgeri Maltzan 1881, p. 163, pl. 9, fig. 7.

Argonauta bottgeri Smith 1887, p. 409, pl. 17, fig. 1-6.

Argonauta Bottgeri Hidalgo 1905, p. 9 (*fide* Hoyle 1909).

Argonauta baettgeri Dall 1908, p. 226, 229.

Argonauta bottgeri Berry 1909, p. 418 (locality record only).

Animal small, pelagic. Male (with the exception noted below) unknown. Body of female smooth, elongate, in general cylindrical, twice as long as broad; posterior part of body with a sharp upward torsion, at least in animals preserved in situ within the shell; rounded below, elevated and bluntly pointed posteriorly, widest in front, much elevated just back of the nuchal region. Mantle margin thin; pallial opening very wide, reaching well above the eyes on either side.

Head small and very indistinctly delimited because so deeply embraced in the mantle. Eyes large, spherical, protruding, a distinct constriction separating them from the head at the base. Funnel of robust proportions, but thin-walled and extremely long, reaching nearly midway of the ventral arms; broad at the base, but thence rapidly tapering to the simple circular aperture at the apex. Funnel organ prominent, of a whitish color; it comprises a large Λ -shaped cushion on the dorsal wall a little anterior of the middle, and a somewhat shorter and narrower elongate-ovate organ on either side of the ventral wall just below it (fig. 5). Locking apparatus well developed; just behind and a little below the eye, the basal margin of the funnel on either side is furnished with a small cartilaginous pit-like depression, which articulates with a posteriorly directed, roughly hook-like nodule on the inner surface of the mantle; just outside this nodule and passing below it parallel to the mantle margin, a shallow, though distinct, groove coincides with a similar sulcus on the outer surface of the mantle, so that the constriction thus formed renders very prominent the thickened band of transverse muscle bordering the mantle opening.

Arms of moderate length, perhaps half again as long as body, sharply separated from body at base by a deep sulcus; order of length 1, 2, 3, 4; dorsal arms somewhat the thickest and strongest as well as the longest, their distal portions furnished with the usual conspicuous wing-like expansions of the marginal membrane, much wrinkled and contracted in preserved speci-

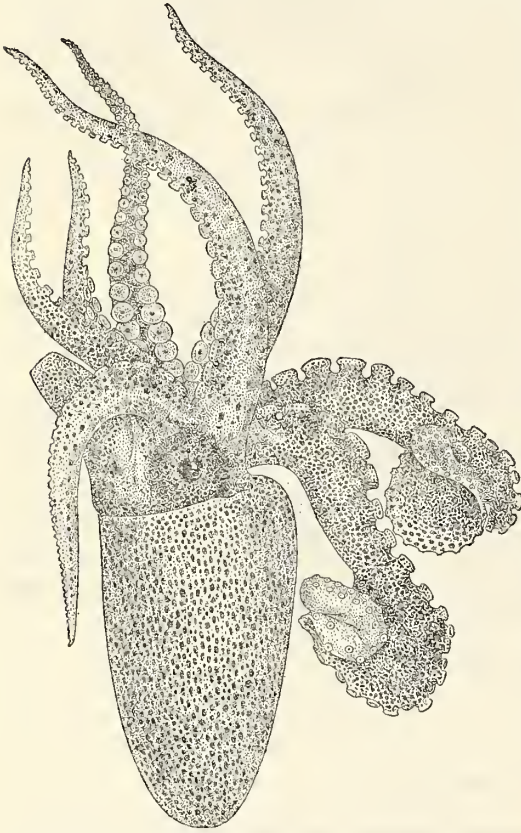


FIG. 3.—*Argonauta bottgeri*, lateral view of female [165], $\times 2$. Drawn by R. L. Hudson. The drawing does not show the characteristic flexures of the body.

mens so that its exact outline is very difficult of determination; remaining arms broad at the base, but rapidly tapering to an attenuate extremity. Umbrella rudimentary, comprising only a short fold interwebbing all the arms for a distance of about three millimeters from their base. Suckers very large, much elevated, 40 to 50 or more in number on each arm (on the dorsal arms over 50 suckers in each row, on the second and third arms about 30 in each row, and on the ventral arms about 18 to 20 in each row); compactly and very regularly ranked in two alternating rows, which on the second arm (and to a very slight degree on the others as well) become ultra-marginal and very widely separated distally (pl. XLVIII, fig. 5); cups flattened and discoid; both rows persistent to the tips of all the arms, though vastly reduced on the

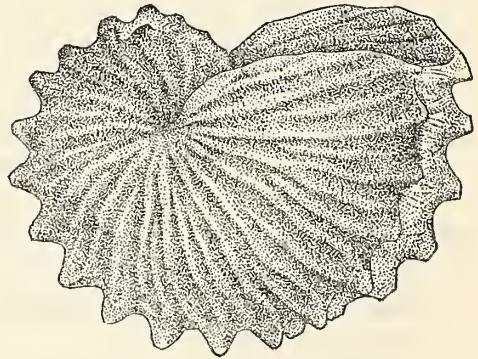


FIG. 4.—*Argonauta bottgeri*, lateral view of shell of female [165], $\times 2$. Drawn by R. L. Hudson.

modified extremities of the dorsal pair, on which latter only the basal 15 to 16 are at all well developed. The funnel is connected to the head dorso-laterally by a pair of delicate bridle-like connective membranes, which are continuous with a delicate keel running along the lower aspect of each ventral arm; otherwise the arms are rounded and devoid of keels or swimming membranes. Dorso-laterally the integument of the head is connected with the dorsal arms by a delicate vertical membrane bridging the sulcus which otherwise separates the arms and head, and two similar but smaller membranes bridge the constriction between the anterior boundary of the eyeball and the lateral arms.

Shell small for the genus, coiled very compactly in an even plane, laterally compressed; the sides ornamented with some 30 or more conspicuous ridges radiating from the shallow depression which is the outward mark of the shell axis; periphery flattened, each angle decorated with a row of bluntly squared tubercles, 17 to 18 of which can be made out on each side; margin of aperture simple, without any trace of lateral expansions or "auricles;" surface finely and quite evenly granulose, the granules most numerous on either side of the shell near the axis and visible without the aid of a lens (fig. 4).

General surface color of animal in alcohol everywhere a pale brownish buff, dotted more or less impartially with numerous fairly large bluish black chromatophores, which are nowhere crowded save on the outer aspect of the dorsal arms and in less degree the dorsal integument of the eyeball. Beak coal black.

As no male animal of this species has come to hand the above description applies only to the female. However, the mantle of the specimen before me was carefully laid open along the medio-ventral line; lying within the cavity, its thickened basal portion lodged snugly just above the left gill between the latter organ and the viscera, was found the detached hectocotylus of a male. This condition is well shown in the accompanying sketch, which indicates the position of the structures in question in situ (text fig. 6); see also the more detailed representation of the hectocotylus in figure 7. The organ comprises a thickened basal portion curved in the shape of a horseshoe about 6 mm. in length by a little more than 4 in breadth, with the inner or sucker bearing aspect outermost; widest between the middle and the base, tapering slightly to a rounded point posteriorly, and more gradually to the acute distal extremity which terminates in a very long and slender thread-like process, lying in a loose coil; the basal portion broadly flattened on its inner surface, the margin of the latter armed with a closely placed row of minute much elevated suckers, about 22 on each border, which are connected by a delicate hyaline membrane; the outer aspect (i. e., inner curve of the horseshoe) is keeled and bears a conspicuous marginal membrane, which even continues along the terminal thread, though

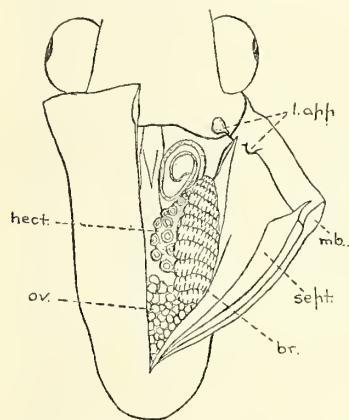


FIG. 6.—*Argonauta böllgeri* [165], ventral aspect of female, with mantle laid partially open to show the detached hectocotylus of the male in situ within the pallial chamber, $\times 2$; br., gill; hect., hectocotylus of male; l. app., locking cartilages of left side; mb., thickened band of muscular tissue bordering mantle margin; ov., gonad; sept., median septum of pallial chamber.

there becoming extremely thin and delicate. The diameter of the basal portion is 2 mm.; the length of the flagellum about 13 mm.

The shell of this specimen was partly full of eggs and young embryos connected into a loose mass by fine filaments and representing various early stages of development. The total number is several hundred at least, the largest scarcely a millimeter in length.

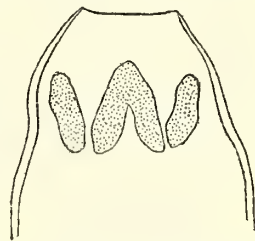


FIG. 5.—*Argonauta böllgeri*, outline drawing of funnel laid open medioventrally to show the funnel organ [165], $\times 2$.

MEASUREMENTS OF ARGONAUTA BÖTTGERI.

	mm.	Length of—	mm.
Total length (to tip of second arms).....	59	Right second arm (inside measurement).....	36
End of body to base of dorsal arms.....	23	Left second arm (inside measurement).....	35
End of body to ventral margin of mantle.....	21	Right third arm (inside measurement).....	28
Width of body near middle.....	10	Left third arm (inside measurement).....	31
Width of mantle anteriorly.....	13	Right ventral arm (inside measurement).....	15+
Width across eyes.....	13	Left ventral arm (inside measurement).....	22
Length of—		Funnel.....	15
Right dorsal arm to expanded portion (inside measurement).....	15	Diameter of largest suckers.....	2
Left dorsal arm to expanded portion (inside measurement).....	17	Diameter of shell.....	31

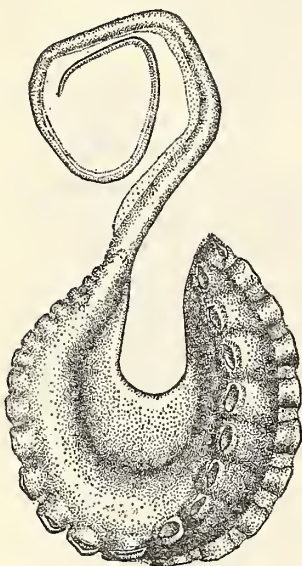


FIG. 7.—*Argonauta böttgeri*, hectocotylus of male [165], $\times 8$.

Type.—?

Type locality.—Unknown.

Distribution.—Mauritius (Smith); Chagos Islands (Smith); Mascate, Philippines (Smith, Hidalgo); China Sea (Smith); Australia (Smith); Hawaiian Islands (*Albatross*).

Specimens examined.—A single adult female containing a hectocotylus and numerous embryos was taken by the *Albatross* in the surface net at station 3927, latitude, $21^{\circ} 31' N.$, longitude, $161^{\circ} 55' W.$, between Honolulu and Laysan Island. The specimen constitutes catalogue No. 214377 United States National Museum [S. S. B. 165].

Remarks.—*Argonauta böttgeri* is not only one of the smallest species of the genus, but one of the most delicately beautiful as well. Its discovery in Hawaiian waters extends its known distribution many thousand miles to the northeast, and further enables me to publish the first detailed description of the animal. When compared with the Mediterranean *A. argo* (see Jatta 1896, p. 191, pl. 8, fig. 3, pl. 18, fig. 15-29), which is the only other form of which I have seen a complete account, important differences are found to be numerous. Most obvious are perhaps the following: In *A. argo* the ventral arms are longest, the third pair shortest; the body is shorter and more inflated; also the suckers are larger and more crowded, and the eyes are larger. Details in the shape and proportions of the funnel organ (narrower in *A. argo*), hectocotylus (also narrower in *A. argo*), and other structures are also noteworthy. The shell of the present species seems unique

in its small size, compact coil, and the circumstance that the auricular expansion at the sides of the aperture, so frequently developed in other species of the genus, are here notable only for their entire absence.

With the exception of the detached hectocotylus as above described, the male of this species was not encountered by the *Albatross*, so unfortunately is still unknown.

Argonauta species.

Argonauta (argo) Linnaeus ?) Berry 1909, p. 418 (locality record only).

From a depth of 127-128 fathoms in the Pailolo Channel, *Albatross* station 3857, were obtained a few badly shattered fragments of a shell which is clearly not referable to *A. böttgeri* [S. S. B. 216]. The nearly complete columella shows the shell to have been auriculate in form, which would indicate that the species represented is probably of the group of *A. argo* and possibly close to *A. pacifica* Dall. The surface of the fragments shows a fine, almost obsolete granulation.

Subfamily TREMOCTOPODINÆ.

Philonexidæ H. and A. Adams 1858, vol. 1, p. 21.

Tremoctopidæ Tryon 1879, p. 130.

Tremoctopidæ P. Fischer 1882, p. 334.

Tremoctopodinæ Berry 1912b, p. 386.

Adult small. Third left arm of the male hectocotylized; its outer surface ornamented with fringe-like papillæ. Dorsal arms of female connected at base by a broad veliform membrane, which extends along their margins, leaving only the very attenuate and frequently decollated extremities free. Remaining arms webbed only at the base, their suckers larger and better developed than those of the dorsal pair. No calcareous egg case or shell. Two large aquiferous pores on the dorsal aspect of the head and a smaller one at either side ventrally just in front of the funnel. Mantle articulating with the funnel by membranous folds; no definite locking cartilages. Funnel organ poorly developed and represented only by a series of longitudinal lamellæ.

Genus TREMOCTOPUS Delle Chiaje 1829.

Tremoctopus Delle Chiaje 1829, T. 70, 71 (*vide* Wülker).

Octopus (Philonexis) d'Orbigny 1835, p. 14.

Philonexis d'Orbigny 1845, p. 200.

Tremoctopus Naef 1912b, p. 199.

Since only the single genus of the group is known, its characters are entirely those of the subfamily.

Type.—*Tremoctopus violaceus* Delle Chiaje 1829 (monotypic), a species originally described from the Mediterranean.

***Tremoctopus violaceus* Delle Chiaje 1829. (Pl. XLIX, fig. 3, 4.)**

? *Tremoctopus violaceus* Delle Chiaje 1829, T. 70, 71 (*vide* Wülker).

Octopus gracilis Souleyet in Eydoux and Souleyet 1852, p. 13, pl. 1, figs. 8-9.

? *Octopus dubius* Souleyet in Eydoux and Souleyet 1852, p. 15, pl. 1, figs. 10-14.

? *Tremoctopus dubius* Tryon 1879, p. 131, pl. 43, fig. 80, 81 (after Souleyet).

Tremoctopus gracilis Tryon 1879, p. 131, pl. 43, fig. 82, 83 (after Souleyet).

Tremoctopus quoyanus Hoyle 1904, p. 12, fig. A.

Tremoctopus sp. (near *quoyanus* d'Orbigny) Berry 1909, p. 418 (locality record only).

Animal small, pelagic. The sexes are so conspicuously dimorphic that a separate description is necessary.

Female: Mantle short; width about equal to length; pouch-shaped, widest anteriorly, and either simply rounded behind or rapidly narrowing to a rounded point; a sharp median longitudinal groove on the ventral surface indicates the position of the median septum of the mantle cavity. Mantle opening very wide and full, extending to a point just above the center of the eye on either side, but well behind it; mantle of scanty extent below, so that its margin barely meets the posterior edge of the funnel.

Head large, flattened; extremely short and broad, the large prominent rounded eyes rendering it usually wider than the body. Eyes not at all pedunculated. Entire surface covered by a loose smooth delicate skin or cuticle of hyaline consistency and unpigmented, which is perforated by four small oval openings—the so-called aquiferous pores—a pair on the dorsal aspect being situated one at the base of each dorsal arm just a little outside the axis of the latter, and another pair about half as large situated one at the base of each ventral arm at either side of the tip of the funnel. Funnel large, compressed, very broad at the base, its outline almost that of an equilateral triangle; only the narrow apex free. Funnel organ composed of a number of longitudinal lamellæ or folds, terminated near the apex by a small acutely pointed valve-like flap. (Pl. XLIX, fig. 4.) The base of the funnel just over the retractor muscles articulates with pocket-like grooves on the inner surface of the mantle by means of a thickened and recurved fold of the posterior margin.

Arms (Pl. XLIX, fig. 3) slender, graceful; decidedly unequal, order of length 1, 2, 4, 3; dorsal arms decidedly longest and when perfect terminating distally in a very long delicate thread-like proeess; second arm pair a little shorter than the first, notably stouter, wider and less attenuate; third arms decidedly

the shortest, usually a very little longer than the mantle in adult specimens and about a third as long as the dorsal pair; all the arms smooth externally, without keels or carinations. Umbrella thin, delicate hyaline; but little developed between the ventral arms, between these and the third pair, and between the latter and the second pair; very extensive between the four dorsal arms, where it attains its maximum, connecting the first and second arm on each side for nearly half their length, but somewhat more deeply cleft between the dorsal arms; continuous along the dorsal margin of the second pair as a delicate web constantly narrowing distad, but along both borders of the dorsal arms it maintains itself as a promi-

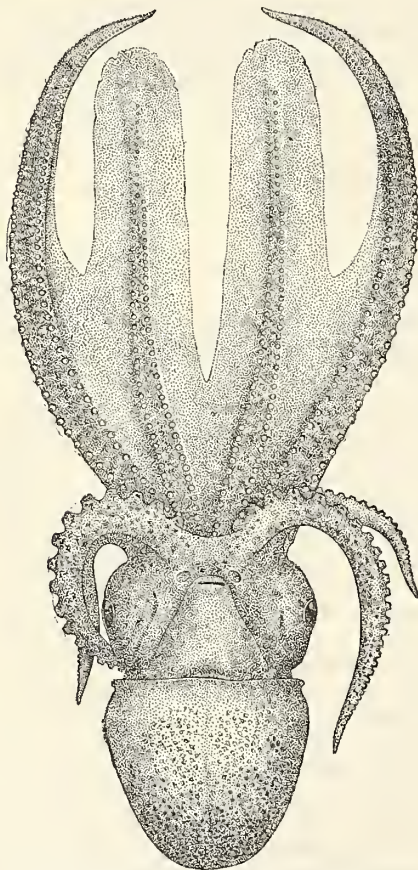


FIG. 8.—*Tremoctopus violaceus*, ventral view of large female [221], from station 3930, $\times 2$. Drawn by R. L. Hudson.

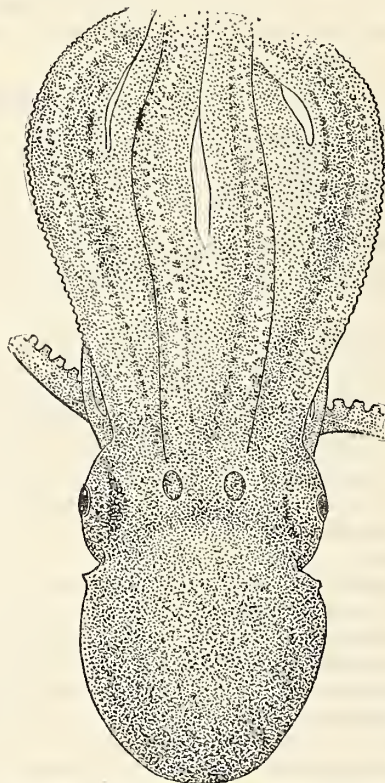


FIG. 9.—*Tremoctopus violaceus*, dorsal view of specimen [221], shown in figure 8, $\times 2$. Drawn by R. L. Hudson.

nent veliform web, oftentimes even broader than the arms themselves, only the filiform extremities of the arms remaining free. In most adult specimens these tips and even the more distal portions of the webbed regions are abruptly decollated.

Suckers small, regularly alternating in two very widely spaced rows, save the basal three which are in a single row and notably larger than any of the remainder except those on the ventral arms which are greatly elevated, cylindrical in shape, much fewer in number, and the rows less widely interspaced. Except at the base the suckers of the four dorsal arms are numerous, much reduced in size, little elevated, and with very small openings; they soon become entirely rudimentary and suddenly crowded laterally

into practically a single row on the distal portion of the dorsal arms, contemporaneous with the general atrophy of the arm itself. The suckers of these arms are ultramarginal except as just noted, and the rows very widely spaced; the suckers of the third arms are somewhat intermediate between this condition and that which prevails on the ventral pair.

Male: Body much smaller, perhaps half as large as that of the female, but quite as variable in shape (figure 10 shows the extreme of rotundity). Arms relatively shorter and more delicate than in the female; the four dorsal arms much less highly specialized, their tips normal, and the very delicate webbing not so well developed. Right ventro-lateral arm hectocotylized, the modification affecting the entire arm, which attains its development in a specialized sac occupying the region which would ordinarily be the base of the arm between the base of the funnel and the eye. (Cf. the account given by Steenstrup, 1857, p. 103-105.) It is visible through the thin overlying integument even in very young specimens as a whitish vermiform body compactly coiled upon itself in such a fashion as to occupy as little space as possible. This arm undergoes a much more rapid growth than the rest of the animal, so that in males measuring about 3 cm. in length (station 4010) the sac is already vigorously crowding the eye and funnel and the animal has consequently a somewhat lopsided appearance; at this stage also the sac has begun to bulge forth by the side of the mouth as a large rounded tumor-like protuberance. In the large mature male from station 4086, the arm had apparently just broken from its sac, but still remained attached by its basal end at the time of capture. At this stage the hectocotylized arm is a highly complex structure as long or longer than the animal itself. It differs very markedly from the hectocotylus of *Argonauta* and may be briefly described as follows:

Much flattened; widest about a third of the way above the constricted and bluntly pointed base. Inner surface bearing about 46 pairs of closely placed suckers ranked in two rather widely interspaced marginal rows; outer surface ornamented with a conspicuous double fringe of long acutely conical papillæ, which extend laterally just above the suckers along the proximal two-thirds of the arm; when the distal third of the arm is reached, the papillæ suddenly cease, the outer surface becoming much flattened, naked, and perfectly smooth. Between the rows of papillæ the skin is minutely ridged and tubercled; near the base an irregular series of small rounded tubercles along the median line gives way on the smooth part to a very fine longitudinal costation; on either side a flanking series of low rounded transverse ridges persists along the entire papillate portion of the arm. The apparent differentiation of the arm into regions extends even to the suckers, the 27 pairs arming the papillate portion of the arm being very different from the remainder. Here the suckers are crowded, thickened, massive, elevated,

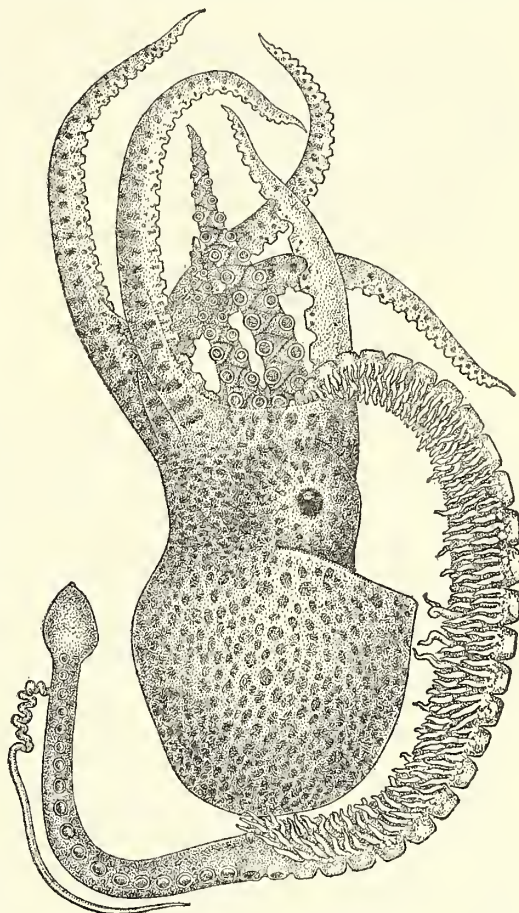


FIG. 10.—*Tremoctopus violaceus*, lateral view of adult male, from station 4086, with nearly ripe hectocotylus [225], $\times 4$. Drawn by R. L. Hudson.

with swollen bases; at first small, they reach their maximum at about the twelfth to fourteenth pairs, whence they again suffer a gradual diminution in size. The apertures of the first 17 pairs are slitlike and so laterally compressed that the openings are scarcely evident; the next 10 pairs smaller and with more open apertures, the aperture of the twenty-seventh where the papillæ cease being wide open. The following 19 pairs are very differently modified: at this point the interspace between the rows widens, the suckers becoming ultramarginal and facing much more laterally; they are smaller, lower, regularly and gradually diminish in size, and have wide, simple, outwardly flaring apertures. The tip of the arm is occupied by a small bulbous expansion devoid of any armature save a slender pointed filiform process extending distally from its pointed tip. Just proximal to the bulb and about three pairs of suckers from the end, the inner surface of the arm gives rise at its middle to a very long delicate colorless thread, which is so coiled upon itself that it can not be entirely straightened out without danger of breaking. This thread appears to be incased in a tenuous hyaline skin, is thickest beyond the coiled portion, and thence tapers to an attenuate and pointed extremity (fig. 10).

Several of the females were examined to ascertain the possible presence of a free hectocotylus within the mantle cavity, but without success.

The dimensions of the hectocotylus above described are as follows:

Total length, exclusive of thread.....	mm. 44
Length of papillated portion.....	28
Length of terminal bulb and process.....	4
Length of thread.....	15+
Maximum diameter.....	3

Young: The series at hand is replete with immature specimens comprising all the later stages of development, the smallest having a mantle length of about 6 mm. Great variation is evident, especially in the shape and general proportions of the arms and body, but all maintain with great constancy the arm formula 1, 2, 4, 3. The third arms in the smallest specimen (station 3799) are so little developed as to be hardly distinguishable. All the arms are relatively much shorter than in the adult, the suckers fewer and larger in comparison, the umbrella very rudimentary and about equally developed all round, and the eyes rendered more conspicuous through their dark coloration. A slightly later stage (station 3878) shows the arms to have grown rapidly and to be already longer than the body. In males of this size the hectocotylized arm is already well advanced, but in the female the extraordinary development of the umbrella and attenuation of the dorsal arms does not become apparent until the animal has attained a much larger size.

Color of specimens preserved in alcohol everywhere a very pale brownish buff, the eyes with a silvery metallic sheen beneath the integument. Chromatophores fairly numerous, especially just above and behind the eyes, but usually more or less indistinct except in the younger specimens where they are fewer in number and much more conspicuous. A single row of three to five large rectangular chromatophores commences along the base of each dorsal arm, but is soon superseded by a double series of much smaller roundish ones. There is also a pair of rather large chromatophores placed transversely between the eyes, a pair of similar but more widely separated ones behind them, and a single small one near the center of the group. Young specimens show in addition a single line of small dark chromatophores bordering the ventral mantle margin, and sometimes an aggregation of similar chromatophores forms a conspicuous spot on each side of the body just behind the eyes (e. g., the individuals from station 3799, where both males and females appear almost different enough in this and other particulars to constitute a different species; the single individual from station 3929 is the only other specimen seen which shares the foregoing peculiarity).

Type locality.—Of *violaceus*, the Bay of Naples, Italy; of *gracilis*, long. 106° W., lat. 8° N., Pacific Ocean (*vide* Tryon).

Distribution.—Of *violaceus*, Mediterranean (Delle Chiaje, Jatta, etc.); middle Atlantic; Japan (Wülker). Of *gracilis*, eastern mid-Pacific (Souleyet); neighborhood of the Hawaiian and Midway Islands (*Albatross*), eastern tropical Pacific (Hoyle, as *quoyanus*); between Papua and Japan (Hoyle); near Mauritius (Souleyet, as *dubius*).

MEASUREMENTS OF TREMOCTOPUS VIOLACEUS.

Number in author's register	221	221	218	219	218	218	217	223	225	218	224	217	218
Station where taken	3930	3930	3878	3926	3878	3878	3799	4010	4086	3878	4011	3799	3878
	♀	♀	♀	♀	♀	♀	♀	♂	♂	♂	♂	♂	♂
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Total length	64+	51+	48	44+	33	30	6	30	24+	25	21	15	14
Length of mantle (dorsal)	16	13	10	10	9	8	3	10	8	7.5	6	6	4.5
Width of mantle	15	11	10	10	9	7	3	7	10	7	6.5	7	4.5
Width of neck	13	10	8	8	8	6	.....	7	8	5	.....	.....	4
Width of head	15.5	12	11	11	10	8	2.5	8	9	7.5	7	6	4.5
Length of funnel	7	7	5	.....	4.5	3	.....	4	5	3.5	.....	2	2
Length of right dorsal arm	40+	37+	34	28+	22	18	2.5	18	10+	16	14	9	9
Length of left dorsal arm	40+	27+	31	31+	22	20	2.5	.....	10+	16	.....	9	9
Length of right second arm	33+	37	28	27	20	16	1.5	16	.....	14	12	8	6.5
Length of left second arm	45	34+	17+	.....	20	18	1.5	.....	14+	14	.....	8	6.5
Length of right third arm	20	15	11	11	10	7	.....	42	.....	.....	.....	2	2
Length of left third arm	20	15	11	.....	10	.....	8	7	4.5	4	3	1.5	.....
Length of right ventral arm	32	25	16	19	14	12	1	.....	14	9	6	2	3.5
Length of left ventral arm	32	25	16	.....	14	.....	1	12	9	6	2	3.5	.....
Length of umbrella between dorsal arms	14	13	9	9	7	3	.....	6	6	3.5	4.5	2	5
Length of umbrella between ventral arms	3	3	2	2	1	1	.....	1	3	1	1	.....	.....
Length of umbrella between dorsal and second arms	22	17	11	11	9	4	.....	6	5	3.5	4	.....	.....

Material examined.—The 31 specimens examined are of various ages but almost equally males and females:

No. specimens.	Locality.	Depth.	Albatross station No.	Sex.	Author's register No.
4	Lat. N. 29° 22', long. W. 130° 31', between Erben Bank and Kaiwi Channel...	Surface....	3799	1 ♂ 3 ♀	217
5	Off Molokini Islet, Kahoolawe....	do.....	3878	2 ♂ 3 ♀	218
3	Lat. N. 21° 13', long. W. 158° 43', between Honolulu and Laysan Island.....	do.....	3926	♂	219
1	Lat. N. 23° 19', long. W. 166° 54', between Honolulu and Laysan Island.....	do.....	3929	♂	220
3	Lat. N. 23° 07', long. W. 170° 50', between Honolulu and Laysan Island.....	do.....	3930	1 ♂ 2 ♀	221
2	Lat. N. 25° 27', long. W. 171° 08', between Honolulu and Laysan Island.....	do.....	3931	♂	222
4	Between Kauai and Oahu.....	do.....	4010	3 ♂ 1 ♀	223
7	.....do.....	do.....	4011	3 ♂ 4 ♀	224
2	Off Puniawa Point, Maui.....	do.....	4086	♂	225

Remarks.—Owing to the great confusion which prevails in the various published accounts of the species of this genus, the identification of even so excellent a series of specimens as the present is not an easy task and the final conclusion attained is not altogether satisfying. It must be admitted that the temptation is very great to unite practically all the alleged species of *Tremoctopus* under the oldest name of which we chance to have knowledge as applied to a member of this group—the *Tremoctopus violaceus* Delle Chiaje 1829. This is in effect what has been done by Jatta ^a (1896, p. 204) and more

^a Jatta includes all the following in the synonymy of *T. violaceus*:

- Octopus velifer* Férussac 1830.
- Philonexis Quoyanus* d'Orbigny 1835.
- Philonexis atlanticus* d'Orbigny 1835.
- Philonexis microstomus* d'Orbigny 1835.
- Philonexis hyalinus* d'Orbigny 1835.
- Octopus (Philonexis) brevipes* d'Orbigny 1835.
- Octopus semipalmatus* Owen 1836.
- Octopus velatus* Rang 1837.
- Octopus Kollikeri* Vérany 1847.

recently by Naef (1912b, p. 199). Wülker has likewise reported under the same name a species of the genus from Japan (1910, p. 5). Not having any material from other regions available for comparison, I have felt constrained to follow the precedent thus made for me, especially since I have not been able to seize upon any characters of sufficient definiteness to separate the Pacific species from the Atlantic. Nevertheless it should be remembered that our knowledge of the group is still woefully incomplete, and a careful account is needed of all the diverse stages which specimens from the various regions pass through during their life history, before absolute confidence can be felt in such wholesale relegation to the synonymy.

Should it eventually appear that there are more species of *Tremoctopus* than recent writers are inclined to admit, I have no doubt whatever that the Hawaiian specimens are identical with the form described by Souleyet as *Octopus gracilis*. Tryon (1879, p. 131) gives the following brief paraphrase of his very inadequate description: "Body rounded, smooth; head small; eyes large, prominent; arms graceful, the upper very long, lower short, connected by a web. Phosphorescent and with metallic reflections when living. Length 24 mm."

Certainly these few lines contain little which can serve either to prove or to disprove the identity of Souleyet's specimen with those obtained by the *Albatross*, but upon turning to the figure we find a representation which accords very well with Hawaiian specimens of the same size, and as both are from the same general oceanic region and the habit of the animals is admittedly pelagic, we find at once a strong *a priori* reason for uniting them. From the present specimens the figure of *O. gracilis* differs most strikingly in its more inflated body (a character of trifling importance) and somewhat wider web between the ventral arms. The eyes are also represented as being semipedunculate, but I suspect that this appearance may be due to the loss of the delicate integument which usually envelops the head. The proportions of the arms are, however, much the same, and it is further noteworthy that a specimen presumably of this species taken by the *Challenger* in the western Pacific differs in no described character from the *Albatross* specimens (Hoyle 1886, p. 71).

With the same form I would be also disposed to unite the *Octopus dubius*, also of Souleyet, especially since the most immature of the specimens before me is almost a counterpart of his figure and is of similar dimensions (6 mm.).

The two female specimens dredged by the *Albatross* in the tropical Pacific, which Hoyle (1904, p. 12) referred with some doubt to *T. quoyanus*, likewise agree perfectly in all the characters stated, have the same curious arrangement of the chromatophores, and are surely conspecific. The single poorly preserved individual taken by the *Challenger* in the south Pacific (Hoyle 1886, p. 70) also is probably identical, so that on the whole it can be affirmed with certainty that few Hawaiian cephalopods exhibit a wider distribution.

The species is one of the most beautiful and graceful of all cephalopods.

Family ALLOPOSIDÆ Verrill 1881.

Alloposidæ Verrill 1881, p. 365.

Argonautidæ (pars) Naef 1912b, p. 197, 198.

Sexes dimorphic, the female larger than the male and often attaining considerable dimensions. Body soft and gelatinous; aquiferous pores lacking. Arms united throughout the greater portion of their length by an extensive umbrella; suckers in 1-2 rows. Hectocotylization affects the whole of the right third arm, which has its origin in a specialized sac in front of the eye, and when mature is most probably caducous.

Genus ALLOPOSUS Verrill 1880.

Haliphron Steenstrup 1859, p. 183 (nomen nudum, *vide* Hoyle).

Alloposus Verrill 1880, p. 393.

Alloposus Verrill 1881, p. 365.

Alloposus Hoyle 1886, p. 72.

Alloposus Naef 1912b, p. 198.

This being the only known genus, its characters are entirely those of the family.

Type.—*Alloposus mollis* Verrill 1880 (monotypic), originally described from off the New England coast.

***Alloposus mollis* Verrill 1880.**

- ? *Haliphron atlanticus* Steenstrup 1859, p. 183 (*vide* Hoyle).
Alloposus mollis Verrill 1880, p. 394.
Alloposus mollis Verrill 1881, p. 366, 420, 434, pl. 50, 51, figs. 3-4.
Alloposus mollis Hoyle 1886, p. 7, 72.
Alloposus mollis Joubin 1895, p. 4, 13, 55, pl. 5, fig. 1, 3, 10, 11, pl. 6.
Alloposus mollis Joubin 1900, p. 11, 30, 127, pl. 5, fig. 14, 15; pl. 17, fig. 1.
Alloposus mollis Berry 1909, p. 418 (locality record only).

Body large, soft, smooth, semigelatinous in consistency, in shape ovoid, widest in front, narrower and rounded posteriorly.

Head short and very broad; when contracted the lids of the large prominent eyes appear to have distinct openings. Mantle opening very wide and full, extending in two broad pouchlike curves from the median point of union with the ventral commissure to a point just past the eye on either side. Medio-ventral septum or commissure well developed, extending nearly to the anterior margin of the mantle, and thence reaching its dorsal attachment through a sinus in the posterior margin of the funnel. Funnel enormous and almost entirely exposed; its apex reaching slightly past the eyes; fused with the ventral integument of the head for almost its entire length. Funnel organ extremely anterior in position and very large, comprising a broad W-shaped pad of a conspicuous brown ochre color; posterior lobes rounded; anterior lobes acute and almost meeting in the median line below (fig. 12).

Arms moderate, decreasing in length and degree of attenuation from the dorsal to the ventral pair (in the present specimen their extremities are badly mutilated); connected at the base by a broad membranous umbrella, the latter attaining its greatest extent between the arms of the dorsal pair which it interwebs for much the greater portion of their length. Suckers large, elevated, deep, their rims of somewhat more massive consistency than the other tissues of the animal; they are in two rows, or rather in a single more or less zigzag row which most conspicuously approaches the two-rowed condition after reaching the margin of the umbrella (at about the thirteenth sucker on the dorsal arms).

The entire integument is of a somewhat stringy semigelatinous consistency. It does not preserve well and is badly torn away from the right side of the present specimen.

Color of specimen preserved in formalin and alcohol a muddy buff, numerous brownish chromatophores are distributed over the dorsal surface and to a considerably less extent below.

MEASUREMENTS OF *ALLOPOSUS MOLLIS*.

	mm.	Length of—	mm.
Total length.....	147+	Left second arm.....	72+
Tip of body to base of umbrella between dorsal arms.....	65	Right third arm.....	65
Length of body.....	50	Left third arm.....	51+
Width of body.....	46	Right ventral arm.....	60+
Width across eyes.....	51	Left ventral arm.....	59+
Length of—		Umbrella between dorsal arms.....	54
Right dorsal arm.....	82+	Umbrella between ventral arms.....	44
Left dorsal arm.....	60+	Funnel.....	38
Right second arm.....	90	Diameter of one of largest suckers.....	4

Type.—In the United States National Museum. A cotype (from *Fish Hawk* station 893) is in the Yale University Museum.

Type locality.—*Fish Hawk* station 880, 252 fathoms, off Newport, Rhode Island, September 13, 1880, three specimens.

Distribution.—Off Newport, Rhode Island (Verrill); off Chesapeake Bay (Verrill); north Atlantic (Hoyle, Joubin), off Marthas Vineyard, Massachusetts (Verrill); off Delaware Bay (Verrill), off the Azores (Joubin).

Pailolo Channel, Hawaiian Islands (*Albatross*).

Verrill gives the bathymetric range of the species as 236 to 1,346 fathoms. Fragments of this species have been obtained from a depth of 1,735 fathoms and likewise from the surface.

Material examined.—One immature female was taken by the *Albatross* in 286 to 290 fathoms, station 4095, northeast approach to Pailolo Channel [S. S. B. 209]. It is catalogue No. 214378 of the United States National Museum.

Remarks.—This interesting species has been described in such excellent detail by Verrill, Joubin, and other writers, that I have endeavored in the above paragraphs to give merely an account of the more salient characters of the species as they appear in the specimen at hand, and to add an account of the funnel organ which has hitherto remained undescribed. The latter is chiefly interesting for its relatively anterior position and great size, for in general outline it does not specially differ from the usual W-shaped type of organ prevalent in most octopod genera.

As this species has not hitherto been reported from the Pacific, there would seem to be strong reasons for doubting its identity with the Atlantic *A. mollis*, if on no other than geographical grounds, yet I have been unable to find any characters which could be used in separately defining it. Perhaps this is due to the obvious immaturity of the present specimen, for an individual observed by Verrill (1881, p. 420) was nearly 79 cm. in length and weighed over 20 pounds, while a single dorsal arm recorded by Joubin (1900, p. 32) is 161 cm. long.

An allied form—*A. pacificus* Ijima (see Ijima and Ikeda 1902, p. 87, footnote)—has been described from the Sagami Sea, Japan. The chief character advanced by the author to separate this form from *A. mollis* is simply that the suckers "are arranged in a single row for the greater part of the arm length, being biserially arranged only in the free tip."

That, unless supported by other structural differences, this feature is of no very weighty importance is readily seen upon examination of the present specimen, for whereas one author might describe the arrangement of the acetabula as unmistakably in two rows, another might as positively assert them to be uniserial. The truth is that, as Hoyle has shown in the case of *Polypus* (1886, p. 76; 1904, p. 18-19), all the suckers are morphologically to be regarded as ranked in a single row, the component members of which have undergone a greater or less lateral displacement to each side in alternation, the resulting biserial appearance being purely secondary.

FIG. 11.—*Alloposus mollis*, ventral view of small female, from the Pailolo Channel 1209, $\times \frac{1}{4}$. Drawn by R. L. Hudson.

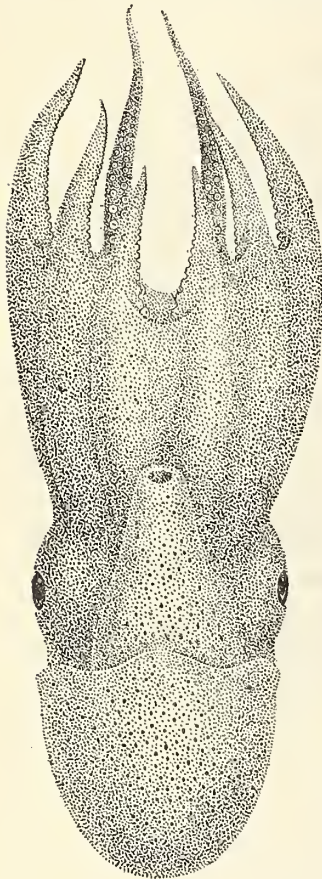


FIG. 12.—*Alloposus mollis* [209], outline drawing of funnel laid open medioventrally to expose funnel organ, natural size.

In this respect *Alloposus* occupies an intermediate position and hence the claims of *A. pacificus* to recognition as a good species can not yet be taken as established, even though in the absence of a complete description of the Japanese form it would be premature to unite the two dogmatically.

Family BOLITAENIDÆ Chun 1911.

Bolitaenidae Chun 1911, p. 20.

Body semigelatinous. Third arms much the longest and largest; suckers on all the arms in a single row. Right third arm hectocotylized, the chief modification consisting in the enlargement of a part or even all of the suckers. Olfactory organ papilliform.

Genus ELEDONELLA Verrill 1884.

Eledonella Verrill 1884, p. 144.

Eledonella Chun 1911, p. 16.

Body gelatinous, weakly pigmented, semitransparent. Hectocotylization affecting only the distal suckers of the arm.

Type.—*Eledonella pygmaca* Verrill 1884 (monotypic), a species of the New England region.

Eledonella species (young).

Bolitaena species Berry 1909, p. 418 (locality record only).

Mantle saccular, much wrinkled, longer than broad. Arms short, incompletely webbed; the 4 to 6 large suckers arranged in a single series. Funnel small, little projecting. Head small. The single specimen obtained is too young for safe determination. It is badly contracted and chiefly characterized by its large eyes, wide mantle opening extending well past the eyes, and short arms, the third and fourth pairs being the longest. The specimen was at first referred to *Bolitaena*, but is more probably an *Eledonella*.

	mm.
Total length.....	15
Length of mantle (dorsal).....	10

From *Albatross* station 4039, 670 to 697 fathoms, off Kawaihae Light, Hawaii [S. S. B. 210].

Family POLYPODIDÆ Hoyle 1904.

Octopidae (pars) d'Orbigny 1838, p. 3; 1845, p. 164.

Octopodidae H. and A. Adams 1853, vol. 1, p. 18.

Polypodidae Hoyle 1904, p. 14.

Polypodidae Naef 1912b, p. 197.

Animals of small to gigantic size. Body short, thick, and usually firm and muscular. Sexes nearly similar. Ventral mantle connection consisting of a pair of shallow folds on the hinder margin of the funnel, with shallow grooves to correspond on the inner surface of the mantle. No aquiferous pores. Arms with one or two rows of suckers and a more or less well-developed basal web. Hectocotylus confined to the extreme tip of either the right or left third arm; a narrow groove or fold in the edge of the marginal membrane terminates in a roughly spoon-shaped copulatory organ at the extremity.

Genus POLYPUS Schneider 1784.

Polypus Schneider 1784, p. 116.

Octopus Lamarck 1799, p. 18 (*vide* Hoyle).

Octopus d'Orbigny, in d'Orbigny and Férussac 1838, p. 17.

Octopus Hoyle 1886, p. 74.

Polypus Hoyle 1901, p. 1-5.

Body short, thick, rounded posteriorly; surface smooth to warty, usually with one or more tubercular cirri over either eye. Arms and umbrella very variable; suckers in two alternating rows, which are perhaps better to be regarded as a single extremely zigzag row. Third right arm hectocotylized.

Type.—*Sepia octopodia* Linné 1758, a European species perhaps identical with *P. vulgaris* (Lamarck 1799). Schneider designates no type and does not even name a species, but the inference seems clear that the *Sepia octopodia* of Linné is the form which he had in mind, especially since at that time this was the only species of the group which had been characterized by a binomial name. Hoyle, however, arrives at the conclusion that *Octopus vulgaris* Lamarck 1799 is available as the generic type.

Polypus hawaiiensis (Souleyet 1852).

Octopus hawaiiensis Souleyet in Eydoux and Souleyet 1852, p. 9, pl. 1, fig. 1-5.

Octopus Hawaiiensis Tryon 1879, p. 118, pl. 34, figs. 44, 45 (after Souleyet).

Octopus hawaiiensis Hoyle 1886, p. 9, 220 (merely listed).

Polypus hawaiiensis Berry 1909, p. 418 (merely listed).

The original description of this species by Souleyet is verbatim as follows:^a

"*Octopus, corpore rotundato, laevi; capito magno; brachiis crassis, basi palmatis.*

"Corps petit, globuleux, lisse dans toute son étendue, l'ouverture antérieure du sac ne comprenant pas tout à fait la moitié de la circonférence; l'entonnoir assez long et grêle.

"Tête volumineuse, aussi large que le corps.

"Bras très-forts, proportionnellement au volume du corps, et légèrement palmer à leur base; ceux des première, troisième et quatrième paires (1), presque égaux en longueur (quatre fois la longueur du sac); ceux de la deuxième paire, d'une longueur un plus grande; les ventouses atternes peu élevées et très-rapprochées.

"Ce poulpe offre partout une teinte d'un gris bleuâtre, très-finement pointillée de noir, ce qui fait paraître sa couleur noirâtre; cette couleur est moins foncée en dessous du sac et surtout à la partie inférieure de la tête.

"Il provient de Hawaii, l'une des îles Sandwich; il ne paraît pas très-commun dans cette localité, car nous n'en avons rapporté qu'un seul individu.

Dimensions.

	Centimetres.
"Longueur totale.....	13
du sac.....	2
de la tête.....	1
des bras (1re, 3e, et 4e paires).....	8
des bras (2e paire).....	10

"Les caractères qui nous ont paru distinguer surtout cette espèce sont: la petitesse, et la forme arrondie du sac, le volume et la longueur médiocre des bras, enfin l'absence de rugosités et d'éminences sur la peau qui est partout parfaitement lisse. Les espèces dont elle se rapproche le plus sont: le *poulpe tehuelche* (O. tehuelchus), de M. d'Orbigny, et le *poulpe brevitentaculé* (O. brevitentaculatus), de M. de Blainville; mais elle diffère de la première de ces espèces par la grosseur et la brièveté des bras, et de la seconde, par la palmature moins considérable de ces appendices et par leur proportion que est tout à fait différente."

Type locality.—Island of Hawaii (Souleyet).

Distribution.—The species has not been again recorded since its discovery.

Remarks.—I am unable to refer any of the numerous specimens of *Polypus* in either the *Albatross* or Stanford collections to this species. Its special characters seem to be the smooth globose body, without cirri or other tubercles, large head, short umbrella, and short robust arms, the second pair of the latter being longest, the others equal. Of the described Hawaiian species, *P. ornatus* and *P. hoylei* are certainly sufficiently distinct, as is also *P. marmoratus* if the description by Souleyet is to be relied upon. The view that the last-named species may really be identical with *P. hawaiiensis* has been suggested by Ortmann (1891, p. 672), and the fact that in the very large series of the genus before me there are no specimens whatever which approximate to the combination of characters alleged to be diagnostic may indicate that an error has somewhere crept in. On the other hand, Tryon regarded *P. hawaiiensis* as very close to or identical with the *Octopus punctatus* Gabb of California, but I think the resemblance is entirely imaginary.

^a As the original volume has only once been accessible to me, I must here mention my obligation to Dr. E. J. Nolan, of the Academy of Natural Sciences of Philadelphia, for sending me the copy of the above description which is here transcribed.

Polypus marmoratus (Hoyle 1885).^a (Pl. XLV; pl. XLVIII, fig. 6.)

Octopus marmoratus Hoyle 1885, p. 227.

Octopus marmoratus Hoyle 1885a, p. 102.

Octopus marmoratus Hoyle 1886, p. 8, 85, 220, pl. 6.

Octopus marmoratus Brock 1887, p. 610, 611.

Octopus marmoratus Ortmann 1891, p. 671.

Octopus marmoratus Joubin ? 1894, p. 35 (fide Wülker).

Polypus marmoratus Hoyle 1905, p. 978.

Polypus marmoratus Berry 1909, p. 418 (locality record only).

Polypus marmoratus Wülker 1913, p. 457.

Body of moderate size, rounded pyriform in shape, broadest toward the posterior, not flattened, but with a distinct median longitudinal depression or sulcus on the ventral surface. Integument as a rule quite smooth, but apt to be much wrinkled above, and with a few large, low, longitudinally elongate tubercles on the dorsal surface; notably more conspicuous than the remainder are one of these tubercles at the base of each dorsal arm, one in advance of the center of the head, and a diamond-shaped quadrilateral of four on the dorsum, besides several lateral ones^b. A series of smaller ridges tends to extend distally from the large tubercles at the base of the dorsal arms out upon the arms, and all show a distinctly bilateral arrangement. In addition to the ridges there is a large conspicuous bluntly conical tubercle just above and behind the center of each eye opening, supplemented by a smaller, more elongated excrescence just in front of the eye, and one other placed diagonally behind. This ornamentation appears to be a reasonably constant feature, at least in the material examined. The mantle opening is not especially wide, extending rather less than halfway from the funnel to the eye.

Head rather small, narrow, rounded, separated from the body by an often slight constriction. Eyes prominent. Funnel small, conical, reaching little more than a third of the distance to the umbrella margin. The funnel organ is well developed and comprises a broad bilobate W-shaped pad on the inner wall of the funnel cavity a little forward of the center. (Fig. 13.)

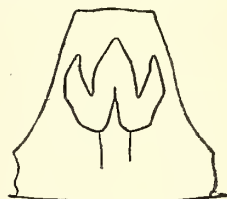


FIG. 13.—*Polypus marmoratus* [175], outline drawing of funnel laid open medio-ventrally to expose the funnel organ, natural size.

^a The principal portion of the description of this species given by Hoyle in the *Challenger* Report (1886, p. 85) is as follows:

"Habitat.—On the Reefs, Honolulu, Sandwich Islands. Three specimens, one ♂, two ♀.

"Sandwich Islands (Copenhagen Museum).

"The Body is round, not depressed, and a little longer than wide. The mantle-opening extends somewhat less than halfway round the body, terminating nearer to the siphon than to the eye, and considerably behind the latter. The siphon is small and acutely conical, and extends about one-third the distance to the umbrella-margin.

"The Head is narrow, and the eyes are prominent, where they have not suffered from compression.

"The Arms are subequal, eight times as long as the body; they are very long and slender, the last character being more marked in the females than in the male; they taper more rapidly at first than near the extremities, which are much attenuated. The umbrella is very wide, especially in the male, where it extends almost one-third up the arms; in the females its extent is only one-sixth. The suckers are rather large, and closely set; in the male a few suckers opposite the umbrella-margin are slightly, but not markedly, larger than the others. The extremity of the hectocotylized arm is small, and has about 10 small transverse ridges.

"The Surface appears to have been smooth, except for a few short ridges placed longitudinally on the back and sides; but the skin is shriveled by the action of the spirit, so that it is difficult to be certain. A conical cirrus is situated above and slightly behind each eye; but in some cases this has been destroyed.

"The Colour is a stone-gray, with dark pigment disposed in veins like those of marble on the dorsal surface of the body, head, and umbrella; the male is much darker, so that the marbling is almost concealed. Traces of an oval spot are seen in front of and below the eye on both sides of one femalespecimen and on one side of the other; but this spot is concealed by the dark colouring in the male even if it exist.

"This species presents in some respects a resemblance to *Octopus bimaculatus*, Verrill, namely, in the general form and proportions, in the enlargement of one or more suckers on the lateral arms, and in the small size of the hectocotylus of the male, as also in the presence of the dark spot on either side in front of the eye. Each, too, has a supra-ocular cirrus, but the conspicuously warted upper surface of Verrill's form and the equally marked smoothness of the *Challenger* specimens, as well as the seemingly constant difference of coloration necessitate their separation.

"It approaches *Octopus hawaiiensis* E. and S., in general form, but differs in the presence of cirri over the eyes."

^b These structures may very likely represent the "few short ridges placed longitudinally on the back and sides" which are mentioned by Hoyle.

Arms stout and muscular, apt to be heavily recurved and coiled in alcoholic specimens; at first rapidly tapering, but attenuate at the extremities; length moderate, perhaps three to four times that of the body; on the average probably subequal, but variable, in the adult the ventral pair usually a little the longest. Umbrella only moderately developed in the specimens seen; about equal all round, and continued as a prominent contractile web along the outer margins of all the arms. Suckers large, rather flattened, and closely set except along the distal portions of the arms, where the two rows become relatively much more widely separated, a character not shown by the figure in the *Challenger* report; first four suckers at the base in a single row. In the male from two to four suckers opposite the umbrella margin on each arm undergo a slight enlargement.

The third right arm in the male is not very much shorter than its mate and the hectocotylized portion is very small. The calamus is poorly developed and does not show the usual papilliform structure; ligula extremely small, its inner surface excavated and provided with about 10 easily obscured transverse ridges. (Pl. XLVIII, fig. 6.)

Color of preserved specimens everywhere a dull drab or stone gray, lighter below and on the inner surface of the umbrella and arms; dorsally the surface is so heavily clouded with a dark slate as to be almost unicolored, but in the lighter areas and when the folds of the skin are stretched apart the dark pigment is seen to be disposed in narrow anastomosing veins which are here and there very conspicuous.^a A series of confluent blotches of similar tint extends along the flattened sides of the arms just outside the suckers and in rough alternation with the latter. In well-preserved material there is a large roundish ocellation a little way in front of and below the eye on either side; the very dark center is surrounded by a broad ring of lighter tint which is not always easy to make out; the entire spot is often somewhat obscured owing to the heavy pigmentation generally, but as it is conspicuously present in at least one of the male specimens examined, it is clearly not to be looked upon as a sexual character. The color in life is not known.

Beak and radula not examined.

MEASUREMENTS OF POLYPUS MARMORATUS.

Number in author's register.....	174	175	183	183	183	183	185
Sex.....	♂	♂	♂	♀	♀	♀	juv.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Total length.....	?	^a 271	59	68	62	59	45
Tip of body to dorsal base of umbrella.....	95	56	17	20	16	16	13
Width of body.....	61	38	11	14	13	12	10
Length of body.....	.....	.....	12	15	12	11	.....
Width of neck.....	38	26	8	10	9	8	7
Width across eyes.....	41	29	11	10	11	10	9
Mouth to tip of right dorsal arm.....	?	^a 182	37	42	41	40	22
Mouth to tip of left dorsal arm.....	^a 310	^a 185	24+	40	41	40	21
Mouth to tip of right second arm.....	^a 340	^a 188	40+	43	46	43	27
Mouth to tip of left second arm.....	^a 335	^a 190	38	48	45	43	29
Mouth to tip of right third arm.....	^a 280	^a 165	24	.....	44	43	31
Mouth to tip of left third arm.....	^a 295	^a 195	42	47	46	42	32
Mouth to tip of right ventral arm.....	^a 345	^a 210	37	35	43	40	29
Mouth to tip of left ventral arm.....	^a 340	^a 215	39	41	45	40	30
Length of hectocotylus.....	4	1.5	.....	.....	.....	.....	.....
Length of umbrella between dorsal arms.....	.....	25	6+	13	11	10	4
Length of umbrella between ventral arms.....	.....	25	8	8	7	10	4
Length of funnel.....	40	20	5	6	5	5	4.5

^a Largely estimated, but figures given for what they may be worth.

	mm.
Total diameter of ocular spot, right side (S. S. B. 175).....	12
Total diameter of ocular spot, left side (S. S. B. 175).....	11
Diameter of dark center of spot, right side (S. S. B. 175).....	8

^a From this feature arises the significance of the name *marmoratus*.

Type.—In the British Museum (Natural History).

Type locality.—"On the Reefs, Honolulu, Sandwich Islands;" three specimens (*Challenger* expedition).

Distribution.—Honolulu Reef, Oahu (*Challenger*, *Albatross*, etc.); Hilo, Hawaii (Stanford University collections); Rotuma (Hoyle); Rimatara (Wülker); Buka, Solomon Islands (Wülker); Stewart Islands (Wülker); Amboina (Joubin); Ceylon (Ortmann).

Material examined.—The following 13 specimens have been examined, the majority of them being rather immature:

No. of specimens.	Locality.	Collector.	Sex.	Where deposited.	Author's register.
1	Honolulu, Oahu.....	Market.....	♂.....	Stanford Univ. Coll., Cat. 2089.....	174
1	Honolulu, Oahu.....	Jordan and Evermann	♂.....	Stanford Univ. Coll., Cat. 2088.....	175
6	Honolulu Reef, Oahu.....	Albatross.....	2 ♀ 4 Juv.	.....	185
4	Honolulu Reef, Oahu.....	Albatross.....	1 ♂ 3 ♀	.....	183
1	Henshaw's Road, Hilo, Hawaii....	.....	Juv.....	Stanford Univ. Coll., Cat. 2090.....	181

Although *P. marmoratus* appears to be a well marked, even if in no way an extraordinary species, it nevertheless exhibits a considerable measure of variability. The four young individuals from Honolulu Reef (S. S. B. 183), which I have assumed to be referable here, indicate this to a remarkable degree, and it may be possible that they are incorrectly determined; they possess a wide flattened head, pale coloration, no ocular markings, and the skin varies from a nearly smooth state to one where the scattered papillæ are erect and bristling. The numerous small chromatophores render the surface finely punctate, and a single slightly zigzag row of somewhat larger chromatophores extends along the outer surface of each arm. The male in this lot is readily distinguishable by its small but well-developed hectocotylus, and by the rather conspicuous enlargement suffered by the seventh and eighth suckers on each of the lateral arms. The remaining suckers are rather small, a little elevated, and equidistant as in the females. The measurements are surprisingly constant, as shown in the above table.

Hoyle compares this species with the Californian *P. bimaculatus* (Verrill) and apparently with justice, although he is undoubtedly correct in regarding the two as distinct. Specimens of the two species placed together have an entirely different aspect and are not likely to be confounded. The divergent pigmentation alone is entirely sufficient for the ready separation of most specimens, and so far as my very limited experience shows the elongate cirri of many *P. marmoratus* do not appear on the Californian form, although the symmetrical arrangement of the tubercles is much the same.

Ortmann (1891, p. 672) has suggested that Hoyle's species may after all be identical with *O. hawaiiensis* Souleyet, in which case the latter name has many years priority and would of course take precedence, but for the present the matter must go over unsettled.

One of the *Challenger* specimens, which is the largest example of the species so far recorded, has a total length of 630 mm. The species is apparently an abundant littoral form occurring in large numbers on the reefs, and is one of the most important of the species used as food. As the most common of the *Polypi* it is likely to be met with in almost any general collection from the region. It is readily distinguishable from the species which usually accompany it by its somber coloration, ridgelike cirri, moderate arms, small hectocotylus, and wide funnel organ, as well as the presence of the three cirri over the eyes and the oculations at the base of the third arms. Being a solid and muscular species, the tissues, particularly of the arms, are apt to undergo a powerful contraction when preserved in alcohol.

Polypus ornatus (Gould 1852).^a (Pl. XLVI.)*Octopus ornatus* Gould 1852, p. 476, figs. 590, 590a.*Octopus ornatus* Tryon 1879, p. 112, pl. 30, figs. 29, 30 (after Gould).*Polypus ornatus* Berry 1909, p. 418 (locality record).

Body of moderate size, subglobose, more expanded and rounded posteriorly. Mantle opening simple, moderately wide, extending on either side to a point about halfway between the eye aperture and the funnel.

Head fairly large, rounded, not excavated above or below; the eyes fairly prominent, with small openings; head and body separated in the nuchal region by a decided constriction. Funnel long, extending for about two-thirds of the distance to the ventral margin of the umbrella, conical and tapering, with a broad base; adherent to the ventral surface of the head for more than half its length; aperture small. Funnel organ well developed, comprising a large W-shaped pad lying nearly midway of the dorsal wall; the median lobe is decidedly longer than the lateral wings. (Fig. 14.)

Arms extremely long, very graceful (pl. XLVI, fig. 1), dorsal pair perhaps as much as seven times the length of head and body taken together, extremely slender and attenuate, the tips almost filiform; disproportionately unequal, the order of length 1, 2, 3, 4; dorsal arms conspicuously the stoutest and longest, the remaining arms exhibiting a decided but very regular decrease in size as we progress ventrally; the ventral arms very slender, less than three-fifths as long as the dorsal pair. Umbrella of small extent; best developed between the dorsal arms and least ventrally, thus giving the mouth the apparent position noted by Gould; it is continuous with a loose, very narrow fold of membrane which runs distad along the outer margins of the arms for a short distance, soon becoming nearly or quite obsolete. Suckers of moderate size, somewhat elevated, and with discoid but fairly deep cups; very numerous and somewhat crowded, 312 being counted on the left dorsal arm of the medium-sized specimen without the aid of a lens, less than a third of them occurring on the distal half of the arm; they are consistently in two rows even at the base near the mouth and at the extreme tip as well; a conspicuous maximum in size is attained a little distance beyond the margin of the umbrella. Third right arm in the male about a third shorter than its mate of the opposite side; on this arm a shallow marginal fold incloses a groove running along the outer ventral angle of the arm; this fold is barely distinct from the main body of the arm itself and is the sole remaining vestige of the marginal web; beginning at the umbrella margin, it terminates in the hectocotylus as the median groove of the flattened conical basal papilla (calamus) of the latter; the principal portion of the hectocotylus (ligula) is a conspicuously thick-

^a The original description of Gould (1852, p. 476) is as follows:

"Body subglobose, the length exceeding the breadth about one-twelfth. Head two-thirds as long as the body, and about half its breadth, of nearly equal width throughout, the eyes being but very slightly prominent. Inferior opening broad, the lip transverse and simple; eyes small, the pupil black, with a silvery iris. Mouth small, situated at the lower third of the umbrella, which is rather small, but well-marked, the membrane not prolonged up the arms. Arms compressed, long and slender, attenuated to a thread, comparative length 2, 4, 3, 1, differing much in size, the upper ones being very robust, the second, third, and fourth pairs being successively more slender, the latter being remarkably slender, not half the size of the upper ones. Cupules of medium size, nearly sessile, crowded, very numerous, extending to the tips of the arms; they commence in a double series on the upper arms, while on the lower ones the first six are in a single series. The surface is coarsely reticulate-papillose, with a series of oblong-oval, smooth, and colorless patches along the back of the arms and around the sac, somewhat resembling bullæ. The ground color is deep orange; beneath somewhat clouded with white; above variegated with five longitudinal, buff stripes, the median one extending to between the eyes, the two lateral ones curving on each side, like meridian lines, and extending only to the neck; between these lines, around the middle of the sac, are deep brown patches, and also between the bases of the arms; there are also brown mottlings along the back of the arms. These, with the pale, bubble-like patches around the base of the sac and along the arms, give a very gay and diversified coloring.

"Length of sac to inferior opening, one and a half inches; length along the back to the umbrella, two and a half inches; breadth of sac, one and three-fourths inches; breadth of neck, one inch; breadth of umbrella from side to side, three inches; breadth above mouth, two inches; below mouth, one inch; length of arms, upper pair, twenty inches; upper lateral, twenty-four inches; lower lateral, about twenty inches; lower pair, twenty-one inches.

"Obtained at the Sandwich Islands at Oahu and Maui.

"No other described species approaches [to] this in form and coloration, except *O. macropus* Risso. The comparative length of arms is different (1, 2, 3, 4), the body is more elongated, and there are no cirrhi about the eyes in the latter species, besides a sufficiently well-marked distinctness of coloration. Described from specimens preserved in spirits, and from a coloured drawing."

ened and expanded spoon-shaped organ, its inner surface broadly but not abruptly excavated and ornamented with numerous irregular transverse wrinkles or grooves. (Pl. XLVI, fig. 2, represents the hectocotylus of an immature specimen.)

The surface ornamentation is very distinctive. Body nearly smooth below; above coarsely and irregularly papillose, the papillæ ordinarily arranging themselves in fairly distinct longitudinal lines, most noticeable on the nuchal region, but extending anteriorly over the umbrella and posteriorly over the dorsum before becoming obsolete. Certain of these papillæ are larger than the others, and in preserved specimens they often become confluent with one another in certain regions of the body to form narrow elongate ridge-like folds of great permanency; along the median line are three of these folds, one extending back from the nuchal region for about a third the length of the body, the second some distance posterior to it in the same line, but much shorter, and a third still farther back and representing but little more than a single large papilla. Lateral to these are three series of similar ridges; two short ones, which, in conjunction with the two chief median ridges, inclose a dark quadrangular area in the middle of the dorsum; two longer folds external to these and paralleling the anterior median fold; and outside these, two still longer but more or less interrupted ridges extending from the upper edges of the mantle opening well past the middle of the body. There are three rather small bluntish cirri just above each eye opening.

Color of specimens preserved in alcohol a dull buff, much clouded above with a more or less washed out reddish chocolate, and below with dull ocher or a livid brown. Each of the integumentary ridges which have been described is inclosed in a prominent band of buff, and a conspicuous series of areolæ or reticulations of the same pale tint are disposed in pairs along the outer surfaces of the four dorsal arms for the greater portion of their length. Gould states the general ground color of the living animal to be orange, but in alcoholic material this fades, and in some specimens the buff bands and areolæ may appear not lighter (as in the specimen to which particular reference is had above), but actually darker and brighter than the surrounding integument. The chromatophores are excessively small and copiously distributed.



FIG. 14.—*Polypus ornatus* [179], outline drawing of funnel laid open medioventrally to expose the funnel organ, natural size.

MEASUREMENTS OF POLYPUS ORNATUS.

Number in author's register.....	382	179	179
Sex.....	♂	♂	♂
Total length.....	<i>mm.</i>	<i>mm.</i>	<i>mm.</i>
Tip of body to dorsal base of umbrella.....	650+	526	263
Length of body (dorsal).....	97	61	38
Width of body.....	68	40	24
Width of neck.....	57	40	25
Width of head.....	35	25	17
Length of—	35	28	19
Right dorsal arm.....	540	305+	224
Left dorsal arm.....	553+	465	225
Right second arm.....	415	360	175
Left second arm.....	480	375	186
Right third arm.....	234	175	112
Left third arm.....	380	310	155
Right ventral arm.....	365	260	126
Left ventral arm.....	380	270	132
Umbrella between dorsal arms.....	56	27	21
Umbrella between ventral arms.....	34	15	13
Hectocotylus.....	9	2	0.5
Diameter of largest sucker.....	9	5	3
Length of funnel.....	40	28	17
Width of mantle opening.....	38	23	15

Type locality.—Oahu (first locality mentioned), Hawaiian Islands (Wilkes expedition).

Distribution.—Hawaiian Islands: Oahu (Gould); Honolulu Reef, Oahu (*Albatross*); Maui (Gould).

Material examined.—Three specimens, all males, are in the *Albatross* collection. All are in an excellent state of preservation.

No. of speci- mens.	Locality.	Collector.	Sex.	Author's register.
2	Honolulu Reef, Oahu.	Albatross expedition.	♂	179
1	Honolulu market. ....	.....do.....	♂	382

Remarks.—The above description is drawn throughout from the specimens taken by the *Albatross*, special reference being had to the larger of the two individuals collected on the reef, as the large market specimen did not come into my hands until afterward and has been chiefly utilized in preparing the description of the hectocotylized arm. It will at once be noted that there are several rather astonishing discrepancies between these specimens and Dr. Gould's description. Perhaps the most important of these is the relative length of the arms, which Gould states to be 2, 4, 3, 1, an utterly different formula from that shown by the present material. As the quantitative differences between the arms of the respective pairs seem altogether too great for such variations to be due to inequalities in the methods of preservation, I am at a loss to account for the discrepancy. It is of course possible that an error has crept in somewhere, for the *Albatross* specimens show not the slightest evidence of any abnormality, while Gould's account of the consecutive diminution in bulk of the arms is entirely in accord with the condition I have described, though not at all what would be expected were his statement of their relative order of length correct. It may be that the type specimen was possessed of some unobserved defect, for where the arms are so slender as in the present species a mutilated and regenerating extremity might be readily overlooked were not special care taken to the contrary. The peculiarly definite color pattern is in all the specimens as striking as Gould's careful description would imply and is so utterly unlike that of any other *Polypus* known to me that I think there can be no doubt as to the correctness of the identification.

Granting this correction in the arm formula, it is interesting to note that the resemblance of this species to the *Polypus macropus* (Risso) becomes even more close than Gould supposed and extends even to such structures as the hectocotylus and funnel organ. (Cf. Jatta, 1896, pl. 23, fig. 8.) A comparison with the figures cited shows that the two species are throughout essentially similar in structure and indicates a very close degree of relationship. The geographical distribution of both forms yields additional strong evidence toward the same conclusion and further supports the idea that *P. macropus* is in fact the parent form. Although *ornatus* is thus far known only from the Hawaiian Islands, *macropus* has a remarkably wide and continuous range, extending from the Mediterranean, on the one hand, through the Red Sea and Indian Ocean to the Malay Peninsula and even to Japan, where it is still a hardy and abundant species. Small differences between the two are numerous and constant, but perhaps are in no way different from the inevitable changes which should be expected to take place in the island species during the long sojourn which it must have had in so isolated an environment. It is curious that the color pattern and surface ornamentation are the features which have undergone the most extensive modification.

***Polypus hoylei* Berry 1909** (Pl. XLVII, fig. 1; Pl. XLVIII, fig. 2-4; Pl. LV, fig. 1.)

Polypus hoylei **Berry 1909**, p. 407, 418, text fig. 1.

Body pouch shaped, rounded, more or less depressed above and below, about as long as broad, widening posteriorly and with an obscure longitudinal groove forming an incipient superficial division of the ventral region into halves. Mantle loose and semigelatinous, very soft to the touch; at

first sight nearly smooth, but upon careful examination revealing a fine regularly granulose papillation, most obscure ventrally. Some examples show indications of low tubercles or cirri on the body, but the only structures of this nature which appear to be at all constant are two soft prominent papilla-like excrescences situated over each eye, one placed just in advance of the eye opening, the other at a slightly greater distance behind this point; when in a state of retraction these eminences are reduced to rounded tubercles having a pore-like pit or indentation at their apex. (Pl. XLVIII, fig. 3.) Mantle opening very small, semicircular, closely embracing the base of the funnel, from which, however, it tends in preserved material to contract away, exposing even the basal folds of the latter. (Pl. XLVII, fig. 1.)

Head large, broad, flattened; separated from the body in the nuchal region by a slight lateral constriction. Eyes large, the integument covering them being usually much puckered about the rather small opening. Funnel large and of robust outline, but short, broad, compressed; broadly adherent above to the head and bound to the latter by loose folds of the integument even as far forward as the basal portion of the umbrella; its extremity is free and reaches a little less than half way to the margin of the latter. Funnel organ well developed and of a very distinctive type; it comprises two narrow but conspicuous V-shaped pads lying on the dorsal inner wall of the funnel cavity, near the tip; they are entirely similar to one another and unconnected. (Text fig. 15, also pl. XLVIII, fig. 4.)

Arms quite short for a *Polypus*, only about two to two and one-half times as long as the head and body; stout, rapidly tapering, the extremities little attenuate; dimensions nearly equal, but exhibiting considerable variability, the third pair apt to be slightly the shortest; connected at base by a wide semitransparent membranous umbrella, extending between the arms about equally all round for from one-third to nearly one-half of their length, but usually of slightly less extent ventrally; this interwebbing is continuous with a conspicuous fleshy fold which extends along the outer margins of all the arms to their extremities. Suckers moderately large, numerous, closely set; regularly alternating in two rows, except at the base, where the first three appear in a single row; soft, but well separated; moderately elevated. According to my observations none of the suckers in the male show any appreciable enlargement or other differentiation one from another. (Pl. LV, fig. 1.)

Third right arm in the male notably shorter and stouter than its mate of the opposite side and prominently hectocotylized, the modification affecting only the tip of the arm and the usual sperm canal formed along the edge of the marginal membrane. The organ at the tip is bluntly conical, somewhat spoon shaped, and the broad excavation on its inner face scarcely or not at all ridged; such ridges, if they occur at all in the larger specimen are rendered very obscure by the loose consistency of the integument, and in the smaller male one or two transverse grooves only may be made out. The relative measurements of the hectocotylus are given in the table of measurements below. With age the ligula becomes apparently somewhat more elongate, as in the smaller male it is very short and pyramidal. The sperm canal terminates distally in the usual basal papilla or calamus, which is here acutely conical, with its inner surface deeply grooved. (Pl. XLVIII, fig. 2.)

Color of preserved specimens a brownish red above, slightly paler or more pinkish below and on the inner surface of the umbrella; no definite color pattern or even any mottlings or other ornamentation of the sort. Entire surface closely punctate with small round reddish brown chromatophores, especially on the dorsal aspect, where they are largely distributed in veins or obscure cloudings, the interstices between which appear as pale reticulations or marblings against a darker background, a feature scarcely to be distinguished without carefully and firmly smoothing out the skin by the fingers.

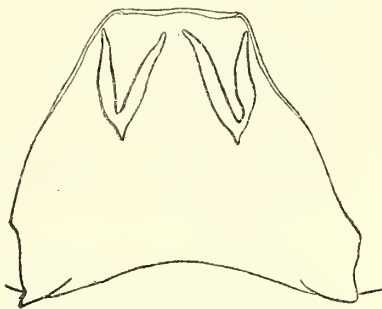


FIG. 15.—*Polypus hoyleri* [176], outline drawing of funnel laid open medioventrally to expose the funnel organ, $\times 2$.

MEASUREMENTS OF POLYPUS HOYLEI.

Author's register.....	166	176	178	177
Sex.....	♂ (type.)	♂	?	♀
	mm.	mm.	mm.	mm.
Total length.....	233	127	108	148
Tip of body to base of umbrella.....	65	41	41	54
Width of body.....	45	31	28	26
Width of neck.....	36	27	26	22
Width of head.....	41	30	27	24
Length of—				
Right dorsal arm.....	109+	89	71	91
Left dorsal arm.....	111+	88	76	49+
Right second arm.....	^a 161+	89	76	105
Left second arm.....	172	82	75	62+
Right third arm.....	116	75	22+	86+
Left third arm.....	158	78	66	93
Right ventral arm.....	104+	85	74	80
Left ventral arm.....	159	85	75	79
Hectocotylus.....	6.5	2		
Umbrella between dorsal arms.....	42	30	20	20
Umbrella between ventral arms.....	41	36	15	17
Diameter of largest sucker.....	3	2	2	2
Length of funnel.....	18	17	12	15
Width of mantle opening.....	22	18	16	16

^a Through an inadvertence the length of this mutilated arm was given in the original description as that of the second arm pair. In the above table the measurements of all the arms were taken along the inner surface from the mouth to the tip. The umbrella was measured externally.

Type.—Cat. no. 214310 United States National Museum [S. S. B. 166].

Type locality.—Hawaiian Islands (*Albatross*); the exact locality and other data are unknown as this specimen was unfortunately not accompanied by any label when it came into my hands.

Distribution.—Among the Hawaiian Islands, in the archibenthal region (*Albatross*).

SPECIMENS OF POLYPUS HOYLEI EXAMINED.

No. of specimens.	Locality.	Depth in fathoms.	Collector.	Sex.	Where deposited.	Author's register.
^a 1	Hawaiian Islands.....	?	Albatross.....	♂	U. S. N. M. Cat. 214310.	166
1	Kaiwi Channel, between Molokai and Oahu.	449-460	Albatross station 4110.....	?	.....	178
1	Vicinity of Kauai Island.....	283-309	Albatross station 4130.....	♂	.....	176
1	.....do.....	257-312	Albatross station 4132.....	♀	.....	177

^a Type.

Remarks.—*P. hoylei* appears to be a characteristic member of the deeper water fauna of this region. Finding no close ally among its neighboring congeners, it is conspicuously characterized by its pale color, soft consistency, unusually small mantle opening, fine surface papillation, short arms, stout hectocotylized arm, and the very unusual shape of the funnel organ. I had originally thought that this species might be a near relative of *P. januarii* (Steenstrup), but a reconsideration of the admirably full description of the latter in the *Challenger* Report has led me to believe that the alliance is not especially close. Both are of deep-water habit and such resemblance as exists between them may well be due to coordination with a similar environment. *P. hoylei* bears a certain resemblance to some of the published figures of *P. sponsalis* (P. and H. Fischer) and one or two similar forms, but it is, I think, sufficiently distinct.

Altogether it is an unusually attractive and interesting species. The specific name is in honor of that master student of cephalopods, Dr. William Evans Hoyle.

[*Polypus fontanianus* (d'Orbigny 1835).]

Octopus fontanianus d'Orbigny 1835, p. 28, pl. 2, fig. 5.

Octopus fontanianus Tryon 1879, p. 123, pl. 37, fig. 54 (after d'Orbigny).

This species is rather uncertainly listed from the "Sandwich Islands" by Tryon (l. c., p. 124) on the authority of a specimen stated to be in the collection of the Academy of Natural Sciences of Philadelphia. It is a South American species and hence its occurrence in Hawaii needs a confirmation which it is not likely ever to receive.

As the collections before me are unusually rich in immature individuals of this genus, some of which do not seem referable to any of the named species, I have thought it worth while to present a brief description of each of the various types into which as a rule the specimens may be easily separated.

Polypus α (young).

Polypus α Berry 1909, p. 418 (merely listed).

Two juvenile *Polypi* in the *Albatross* collection agree in the following assemblage of characters:

Body relatively large, ovate, saccular; much inflated, especially below; broadest *anteriorly* and terminating in an obtuse point or nipple-like projection behind. Mantle approximately smooth, with no definite papillæ, tubercles, or cirri; mantle opening wide, extending to just below the eyes.

Nuchal constriction prominent, almost furrow-like. Head short, broad, flattened. Eyes inconspicuous, slightly protruding, with very small apertures. Funnel large, but not reaching to the base of the arms; in shape bluntly conical.

Arms long, slender, attenuate; very unequal, the order of length 1, 2, 3, 4; connected at the extreme base by a short, delicate umbrella of nearly equal extent all around. Suckers small, numerous, crowded, in two rows.

Color of preserved specimens everywhere pale, without markings of any kind.

With one of the two specimens mentioned are two much smaller individuals (about 27 mm. long), which may represent an even younger stage of the same species, but they differ from those described in their shorter, more uniform arms, much larger eyes, and more oval body.



FIG. 16.—*Polypus* α [192], ventral view of immature specimen from station 3843, × 2. Drawn by R. L. Hudson.

MEASUREMENTS OF *POLYPUS* α.

Number in author's register.	191	192	Number in author's register.	191	192
	mm.	mm.		mm.	mm.
Total length.....	56	45	Length of—		
Tip of body to base of dorsal arms.....	18	15	Right second arm.....	34	28
Length of body (dorsal).....	14	11	Left second arm.....	33	25
Width of body.....	11	9	Right third arm.....	29	21
Width of neck.....	6.5	6	Left third arm.....	29	22
Width of head.....	8	7	Right ventral arm.....	25.5	17
Length of—			Left ventral arm.....	25	17
Right dorsal arm.....	38	30	Umbrella between dorsal arms.....	5	3
Left dorsal arm.....	38	25+	Umbrella between ventral arms.....	4	2
			Funnel.....	6	5.5

SPECIMENS OF POLYPUS α EXAMINED.

No. of specimens.	Locality.	Depth.	Collector.	Author's register.
3	Off Diamond Head Light, Oahu.....	Surface.....	Albatross station 3921.....	191
1	Off South coast of Molokai.....	do.....	Albatross station 3843.....	192

Remarks.—The long, graceful arms give this curiously shaped little *Polypus* a most characteristic spidery appearance. As already indicated, the specimens bear all the evidences of immaturity, and I think there is good evidence that they are but the young of *P. ornatus*, the adult of which they resemble in their arm formula and short umbrella. However, as this is not quite certain and they have so unique a facies of their own, it has seemed best to give them provisional consideration by themselves. In recalling the discussion I have given on a preceding page regarding the relationships of *P. ornatus*, it is interesting to note that these young individuals are exceedingly suggestive of the young of *P. macropus* (Risso) as figured by Jatta in his Naples monograph (1896, pl. 24, fig. 2). Should my belief that these are juvenile *ornatus* be correct, another striking bit of evidence of the close affinity of that species with *P. macropus* is afforded.

Polypus β (young). (Pl. XLVIII, fig. 7, 8.)

Polypus β Berry 1909, p. 418 (merely listed).

Body compact, slightly longer than broad, little tapering, squarely rounded posteriorly; flattened above, more inflated below, with a distinct longitudinal sulcus in the middle, and sometimes a curved constriction or groove nearly paralleling the mantle margin and just behind it. Surface almost smooth, but the dorsum very faintly and regularly papillose, especially between the eyes; just above and a little posterior to each eye opening is a small blunt tubercle, with one or two fainter ones sometimes to be distinguished near it. Mantle opening wide, reaching nearly to the eyes.

Head short, broad, compressed, flattened above. Eyes moderately large and prominent. Funnel short, bluntly conical; barely reaching to the base of the arms; broadly adherent above to the head for a large part of its length.

Arms robust, little attenuate; very short, but about half again as long as the head and body; nearly equal, the dorsal pair as a rule slightly the shortest. Umbrella well developed, but only about half as long dorsally as ventrally and attaining its maximum between the arms of the third and fourth pairs, along which it reaches for about one-third of their length; marginal membranes present on the arms as continuations of the umbrella, but much reduced and almost keel-like. Suckers numerous, large, slightly elevated; closely placed, the first two to four in a single row, the remainder alternating and biserial.

Ground color everywhere a brownish buff, rather pale, but closely dotted above with numerous minute slate-colored chromatophores. A double row of very large, irregular, chevron-shaped chromatophores extends from the base along the outer surface of all the arms, but early becomes obscure on the two ventral pairs. In very young individuals (of a length of 12 mm. or less) the ventral surface of the mantle is ornamented by a number of large irregularly ovoid chromatophores arranged in transverse rows, and there is a single very distinct dark-colored series bordering the nuchal constriction. Such specimens are apt to be a little more globose than those further advanced.

MEASUREMENTS OF POLYPUS β .

Author's register.....	190	196	193	197	Author's register.....	190	196	193	197
	mm.	mm.	mm.	mm.		mm.	mm.	mm.	mm.
Total length.....	51	36	24	10	Length of—				
Tip of body to base of dorsal arms.....	19	15	10	6	Left second arm.....	29	19	13	4
Length of body (dorsal).....	15	12	9	5	Right third arm.....	29	19	14	4
Width of body.....	12	12	9	3.5	Left third arm.....	32	21	14	4
Width of neck.....	11	10	8	3.5	Right ventral arm.....	31	19	14	4
Width of head.....	12	11	9	3.5	Left ventral arm.....	31	19	14	4
Length of—					Umbrella between dorsal arms.....	5	4	.....	1
Right dorsal arm.....	28	21	13	3	Umbrella between ventral arms.....	10	8	.....	2
Left dorsal arm.....	28	20	13	3	Diameter of largest suckers.....	1.5	1+	1	.....
Right second arm.....	29	19	14	4	Diameter of mantle opening.....	10.5	9	.....	3
					Length of funnel.....	7	5	.....	.....

Material examined.—Specimens exhibiting essential accord with the above description were very commonly taken by the *Albatross* in surface hauls. In all some 15 individuals are to be recorded.

SPECIMENS OF POLYPUS β EXAMINED.

No. of specimens.	Locality.	Depth.	Collector.	Author's register.
1	Off Lae-o Ka Laau Light, Molokai.....	Surface..	Albatross station 3821.....	194
1	.....do.....	.....do.....	Albatross station 3837.....	202
2	Off Kalaupapa, Molokai.....	.....do.....	Albatross station 3905.....	200
1	Off Diamond Head, Oahu.....	.....do.....	Albatross station 3907.....	201
1	.....do.....	.....do.....	Albatross station 3911.....	193
1	.....do.....	.....do.....	Albatross station 3912.....	196
2	.....do.....	.....do.....	Albatross station 3921.....	195
1	Honolulu Reef, Oahu.....	Shore.....	Albatross expedition.....	184
1	Between Honolulu and Laysan Island.....	Surface.....	Albatross station 3926.....	199
1	.....do.....	.....do.....	Albatross station 3930.....	190
1	Between Honolulu and Kauai.....	.....do.....	Albatross station 3980.....	198
2	Between Kauai and Oahu.....	.....do.....	Albatross station 4011.....	197

Remarks.—The series of small *Polypi* now under discussion has been the occasion for no little perplexity, especially since it seemed natural to suppose that a species of such apparent abundance ought to be represented in a collection of this size by adults as well, even though I have been utterly unable to bring about such an identification. The more salient characters which separate these specimens, even at a glance, from the other juveniles before me, are the comparative shortness and equality of the arms, the great development of the umbrella, faint papillation, and the prominent chevronlike chromatophores on the arms. It might be safe to propose a new specific name for this form, but in view of the lack of adult material and the unfortunate uncertainty which attaches to *P. hawaiiensis*, it seems the part of wisdom to refrain from adding another name to this already overburdened genus.

Polypus γ (young).

Polypus γ Berry 1909, p. 418 (merely listed).

Several specimens have a different aspect from anything thus far dealt with. The largest of these is the best preserved and may be briefly described as follows:

Body bag-shaped, rather elongate, widest near the middle, without any very prominent ventral groove; length exceeding the width by about one-half. Surface densely papillose above, but nearly smooth below; the papillæ extend thickly over the dorsal aspect of the mantle, head, and umbrella as well as the outer surface of the first two pairs of arms and the dorsal half of the outer surface of the third; they are nearly equal in size, but on the body become longitudinally elongate and appear to be ranked in more or less irregular longitudinal rows, some of them occasionally tending to coalesce to form short

ridges which are usually bilaterally arranged on either side of the body. The most conspicuous of these ridges are two median and two lateral ones, which between them inclose a diamond-shaped space on the dorsum similar to that already described for *P. marmoratus*. There is also a large blunt tubercle above and just behind the center of each eye opening, but this is often so flattened in preserved specimens as to be quite obscure. Mantle opening wide, extending for a little more than half the circumference.

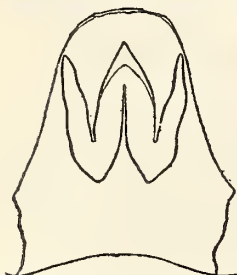


FIG. 17.—*Polyopus γ* [180], outline drawing of funnel laid open medioventrally to expose the funnel organ, $\times 2$.

Head large, elevated, rounded, slightly flattened above. Eyes prominent, with rather large openings. Funnel small, conical; aperture narrow. Funnel organ W-shaped (fig. 17).

Arms moderate, about twice as long as the head and body together; connected at the base by a fleshy umbrella which is best developed between the ventral arms, extending between them for about a quarter of their length; subequal, except the dorsal pair, which are a little the shortest, the order of length 3=4=2, 1; marginal membrane well developed. Suckers rather large, elevated, the first two or three in a single line, the remainder placed moderately close together in two alternating rows.

Chromatophores few below; extremely numerous on the dorsal surface where they appear as exceedingly fine dark punctations. Color in alcohol brownish gray, heavily clouded above with a somewhat darker shade. A very dark stripe borders the upper margin of each arm, while a broad triangular area of a pale color just includes the ocular aperture within its apex and is bounded dorsally by a dark wedgeshaped stripe in front of the eye and a similar one just behind, an arrangement which may be roughly represented by the use of a diagram (fig. 18). There are no ocular markings.

The youngest specimen seen (station 3849) differs from that just described in that a few scattered chromatophores are evident on the ventral as well as the dorsal surface, and certain others are evident as two extremely regular rows of distinct round dots extending along the outer surface of each of the four ventral arms; on the arms of the third pair, however, the dorsal row is almost completely hidden by the prevailing dark coloration. In a somewhat larger individual (station 3905) this peculiar arrangement of the chromatophores is still to be made out but has become much more obscure. Both these specimens have a wider head and more globose body than the larger one above described.

Another specimen taken on the reef at Honolulu by Dr. Jenkins is probably the same, the numerous small differences being apparently due to the better preservation of the *Albatross* material. The papillæ are here considerably less prominent so that their arrangement is more difficult to determine, and the umbrella is considerably shorter between the ventral arms than it is above.

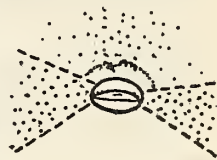


FIG. 18.—*Polyopus γ*, diagrammatic representation of color pattern in region of left eye of specimen from Honolulu [180].

MEASUREMENTS OF THREE LARGEST INDIVIDUALS OF POLYPUUS γ .

Author's register.....	180	188	203	Author's register.....	180	188	203
Sex.....	♀	♀	♀	Sex.....	♀	♀	♀
	mm.	mm.	mm.		mm.	mm.	mm.
Total length.....	143	120	77	Length of—			
Tip of body to base of dorsal arms.....	40	25	25	Left second arm.....	92	95	48
Length of body.....	30	17	18	Right third arm.....	94	91	50
Width of body.....	22	17	16	Left third arm.....	97	92	47
Width of neck.....	17.5	14	13	Right ventral arm.....	93	88	51
Width of head.....	20	17	14	Left ventral arm.....	96	90	52
Length of—				Umbrella between dorsal arms.....	16	18	6
Right dorsal arm.....	87	84	31	Umbrella between ventral arms.....	22	15	12
Left dorsal arm.....	57+	82	40	Diameter of largest suckers.....	3.5	3	2
Right second arm.....	95	90	51	Diameter of mantle opening.....	16.5	13	11.5
				Length of funnel.....	13	11	11

SPECIMENS OF *POLYPUS* γ EXAMINED.

Number of specimens.	Locality.	Depth.	Collector.	Sex.	Where deposited.	Author's register.
1	Honolulu, Oahu	Shore	Wood 1898.....	♀	Stanford Univ. Coll., Cat. 180	
?	Honolulu Reef, Oahu	do	O. P. Jenkins.....	♀	^{2091.} Stanford Univ. Coll., Cat. 188	
1	Off Kaluapapa, Molokai ..	Surface.....	Albatross station 3905.....	♀	^{2092.} U. S. Nat. Mus., Cat. 214384. 203	
1	Off Lae-o Ka Laau, Molokai ..	do	Albatross station 3849.....	♀	Not preserved..... 172	

Remarks.—These specimens are obviously not the young of either *Polypus ornatus* or *P. hoylei*. In some respects they approach *P. marmoratus*, but differ decidedly in coloration, in shape, the absence of ocular markings, and the double row of small chromatophores on the ventral arms of the very young. The funnel organ also appears to be a little different, being narrower and more deeply cleft in the median line. Were it not for the papillated surface and the cirri over the eyes, a relationship with *P. hawaiiensis* might be suggested, but even here these are not the only difficulties. The most conspicuous features of possibly diagnostic importance in addition to those just noted are the short dorsal arms, the subequal dimensions of the remainder, the elongate body, and the relative shortness of the umbrella dorsally. Some of the specimens have a superficial resemblance to *Scaegurys patagiatus* in a general way, but of course lack the marginal fold and other distinguishing features. As in the latter species, the body is remarkable for its compactness and solid consistency in alcohol.

Polypus δ (young).

A single badly mutilated *Polypus* taken on the reef at Honolulu by Dr. O. P. Jenkins and now in the Stanford University collections does not seem clearly identifiable with any of the other forms which have been discussed. It is chiefly characterized by its small ovoid body, smooth save for a few small isolated papillæ; broad head; protruding eyes, ornamented above by two or three minute cirri; the very scanty umbrella, which is much shorter than in any other Hawaiian *Polypus*, not even excepting *P. ornatus*; short dorsal arms, and the extremely stout and long arms of the third and fourth pairs. The arms of the second pair are both mutilated, but with this exception the order of relative length is 3=4.1. The suckers are fairly large, very numerous, and close set. The color is cloudy black above, pale beneath.

In some respects this specimen recalls *P. ornatus*, but in most ways the aspect is notably different. It is No. 186 of the author's register.

MEASUREMENTS OF *POLYPUS* δ .

	mm.	Length of—	mm.
Total length	162	Left second arm	32+
Tip of body to base of dorsal arms	22	Right third arm	37+
Length of body	15	Left third arm	137
Width of body	14	Right ventral arm	133
Width of neck	10	Left ventral arm	140
Width of head	12	Umbrella between dorsal arms	5
Length of—		Umbrella between ventral arms	9
Right dorsal arm	17+	Diameter of largest suckers	3
Left dorsal arm	71	Diameter of mantle opening	9.5
Right second arm	17+	Length of funnel	9

Polypus ϵ (young).

Polypus ornatus (pars) Berry, 1909, p. 418 (locality record only).

Two small *Polypi* taken from a depth of 53–230 fathoms, *Albatross* station 4002, vicinity of Kauai Island, constitute catalogue no. 214,383 of the United States National Museum (S. S. B. 182). They agree in the following characters:

Body small, globose, elevated dorsally; surface obscurely and distantly papillose. Head short and very broad; well separated from the body by a rather deep constriction. Eyes prominent, the aperture to each surmounted by a small conical cirrus and surrounded by a number of more or less distinct smaller papillæ. Funnel of moderate length and width, not quite reaching to the base of the arms.

Arms attenuate; fairly stout, but in appearance slender owing to their great length; in preserved specimens often much tangled and twisted; decidedly unequal, the order of length being 3, 4=2, 1; the third pair vastly the stoutest, largest, and longest, attaining a length of over six times that of the head and body. Suckers small, elevated, little flattened; numerous and closely crowded in each row, but the two rows themselves placed quite distantly from one another along the margins of the arm, the inner surface of which between them is broad and flattened. The first four or five suckers appear in a single row, but distal to these the biserial condition prevails. Umbrella of moderate width, but thin; continuing along the outer edge of each arm to its extremity as a delicate contractile membrane.

Ground color of preserved specimens dull buff, heavily mottled above with dark brown, which, except for a very irregular blotch or spot on either side of the body, does not appear to be distributed with any special regularity. The outer aspect of the arms is mottled and reticulated. Chromatophores small and numerous.

MEASUREMENTS OF POLYPUS ϵ .

	mm.	Length of—	mm.
Total length.....	88	Right second arm.....	52
Tip of body to base of dorsal arms.....	12	Left second arm.....	53
Length of body.....	7.5	Right third arm.....	59+
Width of body.....	9	Left third arm.....	76
Width of neck.....	6	Right ventral arm.....	57
Width of head.....	8	Left ventral arm.....	52
Length of—		Umbrella between dorsal arms.....	4
Right dorsal arm.....	37	Umbrella between ventral arms.....	6
Left dorsal arm.....	37	Funnel.....	5

Remarks.—Upon the first hasty glance these specimens were thought to be young *P. ornatus* and they were originally so reported. Further study has, however, persuaded me that they represent not that species but some other form, the adult stage of which has not yet been obtained. The most distinctive features are the mottled coloration, the extraordinary development of the third arm pair, the wide separation of the two rows of suckers, and the small size of the latter.

Polypus species?

A single specimen obtained by the *Albatross* party from a fish market in Honolulu is represented only by the body and part of the head. It is too mangled for safe determination [S. S. B. 331].

Genus *SCÆURGUS* Troschel 1857.

Scæurgus Troschel 1857, p. 51.

Scæurgus Troschel 1858, p. 298.

Scæurgus Jatta 1896, p. 53, 230.

Animal very similar to that of *Polypus*, but in the male the third arm of the *left* side is hectocotylized
Type.—*Scæurgus titanotus* Troschel 1857 (first species named), a Mediterranean species.

Scaevurgus patagiatus Berry 1913. (Pl. XLVII, fig. 2, 3; pl. XLVIII, fig. 1.)

Scaevurgus, sp. Berry 1909, p. 418 (locality record only).

Scaevurgus patagiatus Berry 1913, p. 564.

Body short, rounded, firm, compact, nearly or quite as broad as long; widest anteriorly or near the middle, evenly rounded behind; much flattened ventrally, with a conspicuous median longitudinal groove; dorsum arched; sides rounded, often flattened or sunken above the periphery in preserved material giving an angular appearance. Mantle opening wide, reaching a little more than halfway between the funnel and eye. Surface (except on the funnel and ventral aspect of the head and arms) everywhere thickly covered with small distinct rounded papillæ or tubercles; on the ventral surface of the mantle they are in the main separate and irregularly but evenly distributed; on the dorsal surface they have a tendency to run together and arrange themselves in more or less irregular longitudinal series, occasionally forming short low ridges similar to those which have been remarked in *Polypus marmoratus*. These ridges also recall those of *P. marmoratus* in their position and frequent bilateral symmetry; four of them form the usual quadrilateral on the dorsum, besides various others more laterally situated. A conspicuous series of similar but less obscure ridges begins a short distance from the base of the arms (affecting all of them except the ventral pair), and extends along their outer surfaces, reaching its maximum on the third pair, where it results in a nearly continuous fold. A narrow keel-like ridge or fold bounds the periphery of the body from a point on either side opposite the base of the funnel nearly to the posterior; in the gap where the resulting lateral folds are discontinuous on the extreme posterior point of the body is a large soft vertical papilla of elongate-conical shape. A large warted or branched papilla is situated obliquely above and behind each eye, with a smaller one just in front and directly over the eye opening.

Head broad, but considerably narrower than the body, from which it is separated by a decided but variable constriction; short, rather small. Eyes large and prominent. Funnel large, conical; broadly adherent above to the head for over half its length, the free extremity reaching about halfway to the umbrella margin. Funnel organ well developed as a broad W-shaped band centering on the dorsal wall of the interior cavity anterior to its center (fig. 19).

Arms robust, squarish, rapidly tapering; of moderate length, but over twice that of the body and head taken together; subequal, the second pair usually a very little the longest. Umbrella well developed, especially between the dorsal arms, where it reaches for nearly one-fourth of their total length; it is continued along the outer margin of each arm to the extremity as a narrow contractile webbing; this membrane appears on both dorsal and ventral angles of the arm, but is invariably widest and most persistent ventrally. Suckers numerous and fairly large; the first two to four in a single row, the remainder quite closely ranked in a double series. In the male one of the suckers on each third arm opposite the margin of the umbrella is obviously larger than the rest.

Third left arm in male a little shorter than its mate of the opposite side and prominently hectocotylized; the conspicuous and ample sperm canal in the margin of the ventral membrane terminates in a long slender acutely conical *calamus*, over one-half as long as the entire hectocotylus; *ligula copulatoria* spoon shaped, its inner surface deeply excavated, nearly smooth, and protected by the heavily incurved margin, which may almost completely inclose the cavity. (Pl. XLVII, fig. 3; pl. XLVIII, fig. 1.)

Color of alcoholic specimens, in general a pale brownish buff, clouded or lightly marbled above with a light chocolate of somewhat varying intensity. Chromatophores small and very numerous, indistinguishable ventrally. Specimens preserved in formalin lose every vestige of pigmentation.

The following notes in regard to the color of this beautiful species during life appear on the reverse of the station label accompanying the type specimen, in the handwriting of Dr. W. K. Fisher: "Ventral surface of body opalescent blue and pink. Light emerald green about eyes. Reddish brown chromatophores on dorsum and sepia ones over eyes. General color of animal when chromatophores are contracted is very pale green."

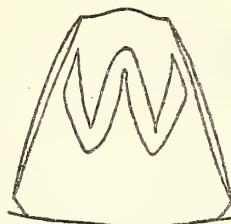


FIG. 19.—*Scaevurgus patagiatus* [205], outline drawing of funnel laid open medio-ventrally to expose the funnel organ, female, $\times 2$.

MEASUREMENTS OF *SCÆRGUS PATAGIATUS*.

Number in author's register.....	204 type.	207	208	205	207	206	207
Sex.....	♂	♀	♀	♀	♀	♂	♂
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Total length.....	152	136	130	104	97	63	60
Tip of body to base of dorsal arms.....	46	40	40	31	27	21	23
Length of body.....	34	31	30	22	20	14	13
Width of body.....	31	31	28	26	19	15	14
Width of neck.....	20	20	21	18	13	12	11
Width of head.....	24	20	22	19	13	13.5	12.5
Length of—							
Right dorsal arm.....	103	92	87	71	59	40	37
Left dorsal arm.....	91	93	82+	73	60	40	36
Right second arm.....	106	93	90	73	59	42	37
Left second arm.....	100+	96	87	72	52+	30+	36
Right third arm.....	105	90	88	68	58	42	34
Left third arm.....	90	89	89	70	55	38	33
Right ventral arm.....	100	86	84	68	53	40	36
Left ventral arm.....	100	88	87	69	57	27+	35
Hectocotylus.....	8						.75
Umbrella between dorsal arms.....	26	25	22	19	16	12	10
Umbrella between ventral arms.....	13	11	18	13	12	8	8
Diameter of large sucker.....	4	3	3	2	1.5	1	.....
Diameter of mantle opening.....	17	18	20	16	11.5	10	9.5
Length of funnel.....	20	13	15	14	10	10	8

Type.—Catalogue No. 214379 United States National Museum [S. S. B. 204].

Type locality.—Albatross station 4079, 143–178 fathoms, bottom of gray sand and foraminifera, off Puniawa Point, Maui, July 22, 1902; one adult male.

Distribution.—Among the Hawaiian Islands in depths of 125 to 165 fathoms as follows: Off Puniawa Point, Maui (*Albatross*); Pailolo Channel (*Albatross*); vicinity of Laysan Island (*Albatross*).

SPECIMENS OF *SCÆRGUS PATAGIATUS* EXAMINED.

No. of speci- mens.	Locality.	Depth in fath- oms.	Collector.	Sex.	Where deposited.	Author's register.
1	Pailolo Channel.....	127	Albatross station 3856.....	♀	.....	205
1	.....do.....	128–138	Albatross station 3858.....	♂	.....	206
3	.....do.....	132–141	Albatross station 4103.....	♂ 2 ♀	.....	207
1	Off Puniawa Point, Maui...	143–178	Albatross station 4079.....	♂	U. S. Nat. Mus., Cat. 214379..	204
a 1	Vicinity of Laysan Island...	148–163	Albatross station 3938.....	♀	.....	208

a Type.

Remarks.—This superb species is the first representative of the circumscribed genus *Scærgus* to be noted from outside the Mediterranean and the immediately adjacent waters of the Atlantic, so that its occurrence as a common species in the Hawaiian Islands occasioned no little surprise. Not only does the present form belong unmistakably to this genus, but it presents so close an approximation to one of the Mediterranean species—*S. unicirrus* (delle Chiaje)—that the separation of the two has only been accomplished by attention to very small details. I have unfortunately not been able to see any actual specimens of *S. unicirrus*, but to judge from the figures given by Jatta (1896, p. 234, pl. 3, fig. 2; pl. 25, figs. 14–22; pl. 26, figs. 1–3) the body of the latter species is a little more elongate; the funnel organ is somewhat different in shape; and the ornamentation of the integument shows certain dissimilarities, notably in that no ridgelike folds are shown to occur on the dorsum and arms, although indications of such a fold on the third arms of the example figured on plate 26, figure 2, suggests the possibility that their absence in the other figures may be due to insufficient representation. The Hawaiian form also appears

to be slightly the superior in size. The widely separated habitat of the two leads one to believe that as both species become better known numerous other differences will undoubtedly be discovered to exist between them.

Dr. Fisher informs me that when living the animal is an object of great beauty, the sheen of its delicate opalescence approaching that of mother-of-pearl. If it is so common a species in this region, it seems rather remarkable that no member of the genus has been brought to light from any other part of the Pacific.

LARVAL OCTOPOD.

There is a very curious but undetermined larval octopod in the *Albatross* collection from station 3802, 150 fathoms, between the Erben Bank and Kaiwi Channel [S. S. B. 386].

Suborder DECAPODA Leach 1817.

Sephinia Rafinesque 1815, p. 139 (*fide* Binney and Tryon, p. 17).

Decapoda Leach 1817 (*fide* Gray).

Decacera de Blainville 1824 (*fide* Verrill).

Decacera de Blainville 1825, p. 366.

Decapoda d'Orbigny 1845, p. 236.

Decapoda Gray 1847, p. 205.

Sephinia Gray 1849, p. 2, 35.

Decapoda H. and A. Adams 1853, vol. 1, p. 25.

Decapoda Kieferstein 1866, p. 1438.

Decacera Verrill 1881, p. 426.

Arms normally 10 in number; the fourth pair originating in special pouches into which they may be more or less completely retractile, and greatly modified to function as highly specialized prehensile organs. Suckers distinctly pedunculate; their apertures equipped with horny or chitinous rings, which may be perfectly smooth, more or less dentate, or with the upper margin greatly enlarged and produced into a long incurved hook. Body short to elongate, rounded or pointed posteriorly, and always with well developed terminal or lateral fins. Head and mantle sometimes continuous in the nuchal region, but more often free and with a cartilaginous articulation. Gladius calcareous or horny; rarely absent; in one genus (*Spirula*) there is an internal coiled and chambered shell. Wherever hectocotylization occurs one or both of either the dorsal or ventral arms undergo the modification.

Highly specialized photogenic organs of many types are of frequent occurrence.

DIVISION MYOPSIDA (d'Orbigny 1845).

Decapoda Myopsidæ d'Orbigny 1845, p. 237.

Myopsidæ Kieferstein 1866, p. 1441.

Myopsidæ Verrill 1881, p. 432.

Myopsida Hoyle 1886, p. 16, 110.

Myopsida Pfeffer 1908, p. 15, 24.

Eyes almost invariably covered by a continuous imperforate membrane or foldlike lid. Horny rings of suckers either smooth or dentate, but never falciform.

There are also numerous important visceral characters such as the symmetrically bipartite liver, genital artery springing directly from the heart, etc.

Family LOLIGINIDÆ (d'Orbigny 1845 em.).

Loligidæ d'Orbigny 1845, p. 318.

Loligidæ Gray 1849, p. 36, 66.

Loliginidæ H. and A. Adams 1853, vol. 1, p. 35.

Loliginidæ Verrill 1881, p. 433.

Loliginidæ Pfeffer 1908, p. 24.

Loliginidæ Naef 1912, p. 243; 1912a, p. 741.

Body elongated and cylindric or cylindro-conical. Mantle free from head in the nuchal region but with a cartilaginous articulation. Eyes without lid-folds, the lens uninterruptedly covered by the outer skin. Fins rhombic to sagittate and terminal, or nearly as long as the mantle and marginal; more

or less acute posteriorly. Left ventral arm of male hectocotylized. Tentacle club with four rows of suckers on the median portion. Horny rings of the suckers usually toothed. Funnel supported dorsally by free muscular bridles; its aperture with a large internal valve. Shell a horny, uncalcified, feather-shaped gladius, comprising a thickened midrib and broad lateral wings.

Genus SEPIOTEUTHIS de Blainville 1824.

Sepioteuthis de Blainville 1824 (*fide* Hoyle).

Sepioteuthis d'Orbigny 1845, p. 319.

Sepioteuthis Wülker 1913, p. 460.

Fins very elongate and marginal, bordering the mantle for nearly or quite its entire length. The outline of the entire animal thus becomes elongate-oval, oval, or elliptical.

Type.—*Sepioteuthis sepiacea* de Blainville 1824 (*fide* Hoyle)=*S. sepioidea* (de Blainville 1823), a species of the West Indian region.

Sepioteuthis arctipinnis Gould 1852.^a (Pl. LIV, fig. 1.)

Sepioteuthis arctipinnis Gould 1852, p. 479, fig. 93.

Sepioteuthis arctipinnis Tryon 1879, p. 152, pl. 62, fig. 211 (after Gould).

Sepioteuthis arctipinnis Berry 1909, p. 418 (merely listed).

Sepioteuthis arctipinnis Wülker 1913, p. 452, 475, 482.

Adult of moderately large size. Body massive, elongate-conical, compressed dorso-ventrally, tapering to a blunt point behind. Mantle very thick and heavy, its anterior margin free, produced forward to a very obtuse and evenly rounded point in the nuchal region; broadly emarginate below the funnel, the emargination bounded by rather acute prominent angles. Fins enormous; attached along the mantle for almost its entire length; widest at about the posterior third, thence gradually tapering anteriorly but ending rather abruptly just before reaching the mantle margin; posteriorly they narrow very rapidly, being not quite continuous around the hinder tip of the body; each fin at its widest point about three-fourths as wide as the body at the same point; thick at base, but with quite thin margins. Entire outline of body, including fins, a very regular ellipse, anteriorly truncate, smoothly curved behind, and broadest at the posterior third as indicated. Cartilaginous articulations of head and mantle as usual in the genus; large and very prominent.

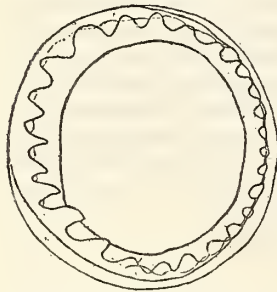


FIG. 20.—*Sepioteuthis arctipinnis* [42], horny ring of sucker from third arm, camera outline, $\times 12$.

Head squarish, of moderate size. Eyes large and prominent; in front of the orbit a pore; behind it the integument is raised into a conspicuous bilobate angled crest, somewhat excavated in front, and with the "olfactory pore" shel-

^a The original description of this species is as follows:

"Body elongated, ovate lanceolate, tapering gradually backwards to a blunt point. Fins broadest at about the posterior fourth, where, together, they equal the width of the body, thence tapering in each direction gradually, and without any angle or dilatation. Color dark purple brown above, paler beneath, everywhere finely punctate with dark brown dots. Head narrower than the body, longer than broad. Sessile arms rather short and stout, armed with two rows of cupules; the superior pair shorter than the head; the first lateral pair a third longer than the superior, and somewhat longer than the head; the second lateral pair a little longer than the first; the inferior pair nearly equal to the second lateral; tentacular arms nearly as long as the body, compressed, the distal third having a lanceolate dilatation, bearing four rows of delicately pedunculated cupules, armed at the margin with delicate black crochets. Mouth large, lip folded and projecting, with two or three minute cupules at each fold.

"Length of body, six inches; of head, two inches; of superior arms, two and a half inches; of inferior lateral arms, three inches; of tentacular arms, eight inches; of cup-bearing portion, two and three-fourths inches; greatest width, two and a half inches.

"From the island of Maui, Sandwich Islands.

"It closely resembles *S. loliginiformis*, D'Orb., from the Red Sea, which has a much more decided expansion of the fins at its posterior half, and the tentacular arms are much shorter. The narrow and regularly tapering fin is its distinguishing character. Described from specimens in spirits." (Gould 1852, p. 479.)

tered within the bay of the ventral angle.^a Funnel very large; broad at the base and tapering bluntly to the wide-valved aperture. Funnel organ enormous, comprising a very large deeply bilobate pad occupying most of the posterior two-thirds of the dorsal wall of the funnel, and a pair of much shorter bean-shaped ventro-lateral pads.

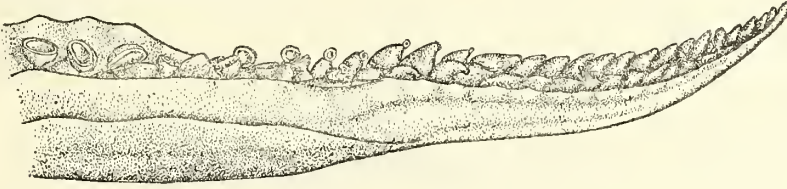


FIG. 21.—*Sepioteuthis archipinnis* [45], hectocotyzed portion of left ventral arm of male, $\times 3$.

Arms of moderate length, stout, squarish, unequal, the order of length 3, 4, 2, 1. All the arms are outwardly keeled and have a broad trabeculated marginal membrane bordering the sucker-bearing area, this membrane reaches its maximum on the central portion of the third arms and is least developed on the ventral pair. Both outer margins of the ventral arms conspicuously keeled, the dorsal keel developed as a broad thickened membrane ensheathing the base of the tentacle. Suckers large, regularly alternating in two rows; the horny rings of the largest armed with 25 to 26 stout acute teeth (fig. 20).

The hectocotylyzation is as usual in the genus; for about 19 pairs the suckers of both rows are normal; at this point on the left ventral arm the cups become suddenly reduced (although persisting to about the twenty-second pair) and the pedicels correspondingly enlarged; the latter continue as stout conical papillæ to the tip of the arm, those of the dorsal row being considerably larger than their ventral companions (fig. 21).

Tentacles of variable length, laterally compressed; both outer and inner faces subearinate at the base, the inner becoming flattened and transversely striate distally; on the distal half of the club the outer carina becomes expanded to form a heavy fleshy keel. Club large, expanded; its margins bordered by a crenulate membrane strengthened by rather flattened and illy-defined transverse trabeculæ. Suckers crowded, in four rows; largest at about the middle, especially those of the two central rows, diminishing toward either end; distally all the suckers become very minute, those of the ventral row becoming the largest, of the dorsal smallest; horny ring of a large median sucker armed with 17 to 19 strongly incurved teeth.

Buccal membrane 7-lobed, the lobes pointed and bearing a few very minute suckers near their tips.

Gladius lanceolate; with a heavy midrib and distinct submarginal thickenings (fig. 22).

Color of preserved specimens a brownish buff everywhere beneath the large slate-colored chromatophores. The latter very variable in size; very numerous and much run together dorsally, fewer and more scattered on the ventral aspect; absent from the ventral surfaces of the fins.



FIG. 22.—*Sepioteuthis archipinnis* [45], dorsal aspect of gladius of male from Honolulu, $\times \frac{1}{2}$.

^a My previously published account of this structure in *S. lessoniana* (1912b, p. 402) is ambiguous and very misleading respecting the position of the olfactory pore. The pore is not really dorsal in position, but sheltered within the ventral lobe of the crest as stated above.

MEASUREMENTS OF SEPIOTEUTHIS ARCTIPINNIS.

Number in author's register	45	42	Number in author's register	45	42
Sex.....	♂	♀	Sex.....	♂	♀
Length of mantle (dorsal).....	<i>mm.</i> 187	<i>mm.</i> 163	Length of—	<i>mm.</i>	<i>mm.</i>
Width of mantle anteriorly.....	54	55	Third arm.....	87	81
Width across fins at widest point.....	120	90	Ventral arm.....	73	77
Width of fin at widest point (ventral).....	38	25	Hectocotylized portion.....	23	.....
Width of head.....	41	38	Tentacle.....	.....	184
Length of—			Tentacle club.....	.....	60
Dorsal arm.....	58	48	Diameter of largest suckers on tentacle.....	3	4
Second arm.....	71	72	Diameter of largest suckers on third arms.....	3	3

Type locality.—Island of Maui (Gould).

Distribution.—Honolulu, Oahu (*Albatross*, Jenkins, et al.); Maui (Gould); Bertrand Id., north coast of Papua ? (Wülker).

SPECIMENS OF SEPIOTEUTHIS ARCTIPINNIS EXAMINED.

No. of specimens.	Locality.	Collector.	Sex.	Where deposited.	Author's register.
1	Honolulu, Oahu.....	Jordan & Evermann.....	♂	Stanford Univ. Coll., Cat. 2098.....	45
1	.....do.....	Brandt.....	♀	Stanford Univ. Coll., Cat. 2099.....	44
1	Honolulu Reef.....	O. P. Jenkins.....	Juv.	Stanford Univ. Coll., Cat. 2100.....	43
1	Honolulu Market.....	Albatross expedition.....	♂	U. S. Nat. Mus.....	43

Remarks.—The large male from Honolulu, which is the subject of the major portion of the preceding paragraphs, shows certain differences from the description of Gould. Its fins are proportionately wider (the two taken together considerably more than equaling the body in width at their widest point), and the ventral arms are longer, considerably exceeding the head in length. These divergencies do not seem important, however, and on the whole the specimens indicate that *S. arctipinnis* is probably to be regarded as a good species, even though not a very strongly differentiated one.

As compared with male specimens of a near ally, *S. lessoniana* Férussac, from Wakanoura, Japan, the following differences are presented: The animal is smaller, the body a little more slender, more regularly tapering, and the posterior extremity somewhat more acute. The fins do not extend quite so far forward, they do not possess so symmetrically curving an outline, and the point of their widest expansion is at the posterior third instead of at near the middle. The "olfactory crest" is less developed and its lobes angled rather than rounded. The minutiae of the hectocotylized arm are slightly different, although this may be due to the method of preservation. Lastly, the suckers of the sessile arms have a decidedly fewer number of teeth on their horny rings; the variance between the horny rings of the tentacular suckers is very slight but in the same direction. The marginal thickenings of the gladius are also worthy of note, but these have already been called to attention by Tryon. On the whole the relationship between the species is exceedingly close, but so far as my material goes the two may be readily separated by means of the characters noted.

This is another important edible form.

Genus *LOLIGO* Schneider 1784.

Loligo Schneider 1784, p. 110.

Loligo Lamarck 1798 (*fide* Hoyle); 1799, p. 11 (*fide* Jatta).

Loligo Verrill 1881, p. 307.

Body elongate, tapering posteriorly. Fins terminal; rhomboidal in the young, in the adult more or less sagittate.

Type.—*Sepia Loligo* Linné 1758. As in the case of *Polypus*, Schneider mentions no type or other species, but the clear inference is that *Sepia loligo* Linné was what he had in mind, a conclusion supported by the fact that this was the only species of true *Loligo* which was at that time possessed of a binomial name. Because of the great uncertainty attaching to Linné's species, Hoyle considers *L. vulgaris* Lamarck 1798 to be the type of Schneider's genus as it is that of Lamarck.

[*Loligo gahi* d'Orbigny 1835.]

Loligo gahi d'Orbigny 1835, p. 60, pl. 3, fig. 1-2.

Loligo Gahi Tryon 1879, p. 144.

Tryon gives us an alleged record of this species from the Hawaiian Islands in the following words: "Specimens in Mus. Phila. Acad., said to come from the Sandwich Islands, agree well in the dentition of the rings with this species." As this is a characteristic Peruvian and Chilean species there is no doubt that the citation is an error.

Strangely enough the above is the only record I have been able to find of the presence of any member of the cosmopolitan genus *Loligo* in Hawaiian waters, and I am unable even with the aid of the large collection now in hand to affirm its occurrence there.

Family SEPIOLIDÆ Keferstein 1866.

Sepiolini Steenstrup 1861 (*vide* Hoyle).

Sepiolidæ Keferstein 1866, p. 1443.

Sepiolidæ Verrill 1881, p. 347, 416.

Sepiolidæ Joubin 1902, p. 80, etc.

Sepiolidæ Pfeffer 1908, p. 24, 31.

Sepiolidæ Naef 1912, p. 243, 244.

Body short, thick, rounded posteriorly. Fins large, separate, ovate or rounded, attached laterally near the middle of the body. Eyes with a thickened ventral fold or false lid, and sometimes a dorsal fold as well. Median septum of mantle cavity reenforced by a pallial retractor muscle joining the mantle to the body. Internal shell a very rudimentary uncalcified gladius, often entirely absent. Eggs large and few. A photogenic gland is often present in the pallial cavity overlying the ink sac; from it a luminescent secretion is emitted.

Subfamily SEPIOLINÆ Naef 1912.

Sepiolini Appellöf 1898, p. 623.

Sepiolinæ Naef 1912, p. 246, 247.

Mantle margin united with head in nuchal region by a band-like commissure. Left dorsal arm hectocotylized. Photogenic glands often absent; when present of elongate form, well separated, and more or less lateral in position.

Genus EUPRYMNA Steenstrup 1887.

Euprymna Steenstrup 1887, p. 66.

Euprymna Steenstrup 1887a, p. 88-90 (42-44).

Euprymna Hoyle 1904, p. 24.

Euprymna Wülker 1910, p. 9, 26, etc.

Euprymna Naef 1912, p. 247.

Suckers of sessile arms in four rows, except at tip and extreme base; on tentacle club long stalked, very minute, urceolate, and in very numerous (more than 16) rows. Nuchal commissure over one-third as broad as the body. Left dorsal arm of male hectocotylized, the distal suckers closely palisaded together and of very characteristic structure; the remaining arms differ from those of the female in the possession of certain peculiarly enlarged suckers. Large elongate photogenic glands present. Gladius wanting.

Type.—*Inioteuthis Morsei* Verrill 1881 (species first mentioned), a common Japanese species.

Euprymna scolopes Berry 1913. (Pl. XLIX, fig. 5-8, text fig. 23-26.)*Euprymna morsei* Berry 1909, p. 418 (locality record only), not of Verrill.*Euprymna scolopes* Berry 1913, p. 564.

Animal small, sepioliform. Body short, thick, rounded; the transverse diameter usually equal to about two-thirds to four-fifths of the length, but the entire outline and proportions very variable. Fins large, semicircular; attached with a considerable degree of obliquity a little in advance of the middle of

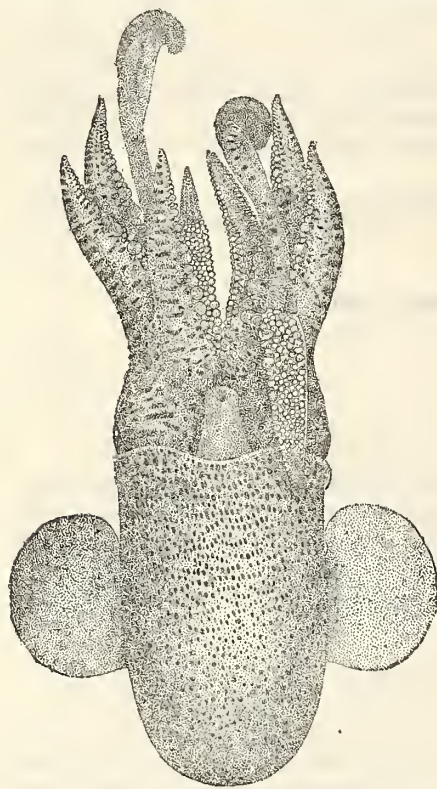


FIG. 23.—*Euprymna scolopes*, ventral view of male [320] type, $\times 1\frac{1}{2}$. Drawn by R. L. Hudson.

the body; broadest posteriorly; anterior lobe conspicuous and abruptly notched at its inward margin, so that the fin is actually attached along only about the posterior two-thirds of its length. Mantle united with the head in the nuchal region by a broad commissure, so that the pallial aperture extends but a very small distance past the eyeball, which it partially encompasses posteriorly. Ventrally the mantle margin is sinuous and somewhat produced forward on either side of the funnel, though with a more or less conspicuous emargination just beneath the latter.

outer surfaces of ventral arms rounded, the others all furnished with a delicate colorless carina or fold of membrane, best developed on the third arms, but sometimes obscure even there. Umbrella rudimentary or lacking (in some specimens) between the dorsal arms as well as those of the ventral pair; better developed between the dorsal and second arms and between these and the third pair; between each third arm and its ventral companion it forms the usual broad sheath inclosing the base of the tentacle. Suckers on all the arms in two rows at the extreme base, but the succeeding pairs soon undergo an alternate lateral displacement, resulting in a four-rowed condition, which prevails practically to the extremities of the arms; pedicels stout, conical; cups spherical, with small apertures, and easily lost through abrasion; horny rings of larger suckers (at least in the female) smooth.

In the female the suckers of the various arms are relatively minute and of subequal size at homologous regions of the arms, but in the male a number of important modifications occur. In specimens of the latter sex the left dorsal arm is conspicuously hectocotylized; the first four pairs of suckers at the base

Head somewhat broader than long, its transverse diameter usually a little less than that of the mantle, but sometimes slightly exceeding it; broadly flattened above, somewhat hollowed out below for the accommodation of the funnel. Eyes somewhat swollen, large and prominent. Funnel elongate conical; the extremity nearly cylindrical, with thick walls, and a small apical aperture; tip nearly or quite attaining the base of the ventral arms; interior walls of tip minutely striate longitudinally; the minute spoon-shaped valve is situated on the dorsal wall just back of the striated area and is succeeded posteriorly by a region of strong transverse striation. Funnel organ posterior in position and very similar to that of *E. morsei*

(see Berry 1912b, p. 409). Arms rather short, stout; usually as long as or a little longer than the mantle; unequal, the brachial formula consistently 2, 3, 4, 1, although the dorsal arms are only a little shorter than the ventral; usually as long as or a little longer than the mantle; unequal, the brachial formula consistently 2, 3, 4, 1, although the dorsal arms are only a little shorter than the ventral;

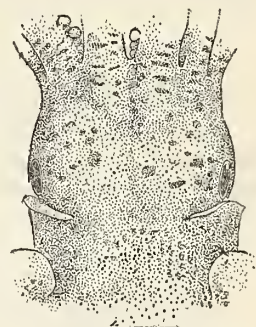


FIG. 24.—*Euprymna scolopes*, dorsal view of head of male [320], $\times 1\frac{1}{2}$. Drawn by R. L. Hudson.

are in two rows; at the point where the 4-rowed condition commences the ventral series contains two (sometimes apparently only one) modified papillæ, usually differentiated from the ordinary sucker pedicels, with which they are undoubtedly homologous, by their more slender shape and oblique position. Distal to this point occur about 10 quartets of small globular suckers similar to those of the female, except that those of the dorsal row are a little the largest. Beyond its basal third the arm becomes much swollen, while the suckers of the two ventral rows suddenly give place to a compactly crowded, rather irregular series of massive transversely elongate and compressed papillæ, bearing a mouth-like aperture in place of a true sucker at their inner apex, and continuing in constantly diminishing size to the tip. The suckers of the two dorsal rows continue normally for two or three pairs farther than the ventral, when they too undergo modification, appearing as a crowded alternating double series of swollen tubercles, their pedicels not transversely compressed nor so closely palisaded as those of the ventral papillæ. As in the case of the latter, the suckers themselves are reduced to mere lip-like slits at the apices. In all cases these apertures appear to be guarded by a highly modified very minutely toothed horny ring. Except in minute details, the whole structure is thus seen to offer a close parallel to that which has been described for *E. morsei*.

The right dorsal arm is more slender than the left and approaches more closely than any of the other arms to the condition observed in the female; all the suckers crowded, minute, but those of the median rows rather the more so; the suckers of the ventral row in their turn slightly smaller than those of the dorsal series. On the arms of the second pair the suckers of the outer rows are larger than those of the inner; about six of the basal suckers of the dorsal row are notably larger than the remaining members of the series; in the ventral row about eight suckers along the distal two-thirds of the arm are greatly enlarged (though not to such an extent as in *E. morsei*) and occur in alternation with other suckers of the same row having scarcely a third the diameter. The third arms likewise have their marginal suckers larger than the inner, 8 to 10 alternating suckers of the ventral row being much enlarged. The same condition prevails on the ventral arms and is only a little less conspicuous; here three or four suckers of the dorsal series are similarly affected, though in less degree.

Tentacles very variable in length, elastic, compressed; keeled near the extremity, inner surface flattened. Club little expanded; closely recurved and coiled upon itself at the tip; inner aspect villous in appearance, due to the exceeding minuteness of the numerous suckers. Individual suckers deeply urceolate, slightly oblique, the so-called papillary area very wide, so that the inner aperture is much reduced; pedicels very long, their basal portions columnar and closely packed together, so that the suckers are mobile only by virtue of a much shorter constricted peduncle, which serves to join the cupules to the main stalk.

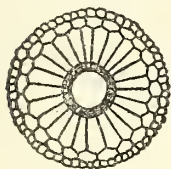


FIG. 26.—*Euprymna scolopes* [323], diagrammatic representation of papillary area of tentacular sucker, greatly enlarged.

Buccal membrane seven-pointed; thickened, with rugose edges.

Gladius, none.

Color of preserved specimens a pale brownish buff, sometimes spotted above with conspicuous well-defined dark dots, sometimes heavily clouded (especially over the dorsal surface) with dark bluish slate, depending upon the state of expansion or contraction of the chromatophores. There is an especially conspicuous series of large transversely elongate chromatophores ranked in close succession along the outer aspect of each of the sessile arms, and a very similar series of smaller chromatophores extends along the distal portion of the tentacle stalk. The following note as to the color of this species during life appears in Dr. Fisher's handwriting on the reverse of one of the original labels: "Sepia: Chromatophores brown yellow and sepia eyeballs and visceral sac tinged with iridescent Nile green and blue."

Larval or young specimens differ most conspicuously from the adult in their shorter more inflated mantle, larger head, and the fewer and more definite chromatophores. The secondary sexual characters begin to become conspicuous at least as early as the stage with an average mantle length of about 10 mm.

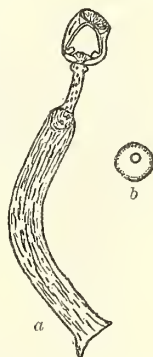


FIG. 25.—*Euprymna scolopes*: a, sucker from tentacle club [323], from a mount in balsam, greatly enlarged; b, oral aspect of horny ring from same, same scale.

MEASUREMENTS OF EUPRYMNA SCOLOPES.

Number in author's register.....	187	319	321	312	320	323	323	308
Sex.....	♀	♀	♀	♀	♂ (type)	♂	♂	♂
Total length.....	mm. 128	mm. 54	mm. 50	mm. 20	mm. 63	mm. 74	mm. 52	mm. 44
Tip of body to base of dorsal arms.....	41	35	32	13	35	36	31	18
Tip of body to tip of second arms.....	71	54	47	20	59	61	49	32
Tip of body to mantle margin.....	28	25	23	9	25	24	21	12
Width of mantle.....	21	20	18	9	16	18	14	11
Length of fins, total.....	10	13	12	5	12	13	10.5	7
Length of fins along plane of attachment.....	8	9	8	3	8	9	6.5	4.5
Width across fins.....	38	35	33	14	29	36	26	19
Width of dorsal commissure.....	9.5	10	10.5	5.5	10	12	10.5	7
Length of head.....	13	11	11	4	10	13	10	6
Width of head.....	18	17	16	8	15	18	15	11
Length of—								
Right dorsal arm.....	28	16	15	7	20	20	16	11
Left dorsal arm.....	27	16	14	5.5	20	20	16	8.5
Second arm.....	38	23	20	9	27	27	21	15
Third arm.....	34	21	19	8	23	23	20	13
Ventral arm.....	31	18	15	7	20	21	18	11.5
Tentacle.....	92	22	22	8	31	43	24	28
Tentacle club.....	16	6	7		5.5	6	5	4
Funnel.....	16	11.5					12	

Total length of smallest specimen examined 8 mm.; of mantle of same 3 mm.

Type.—Catalogue No. 214380, United States National Museum [S. S. B. 320].

Type locality.—Albatross station 3905, surface, off Kalaupapa, Molokai, April 30, 1902; 13 specimens.

Distribution.—Known only from the region of the Hawaiian Islands (*Albatross*, Jenkins, Berndt).

Material examined.—The 64 specimens of this species which have been examined are to be catalogued as follows:

Number of specimens.	Locality.	Depth in fathoms.	Collector.	Sex.	Where deposited.	Author's register.
1	Off Lae-o Ka Laau Light, Molokai.	Surface.	Albatross station 3821.....	♂	.....	309
1	Off Avalu Point, Lanai.....	Surface.	Albatross station 3829.....	♀	.....	311
1	Off Lae-o Ka Laau Light, Molokai.	60-64	Albatross station 3846.....	♀	.....	318
1	Pailolo Channel.....	127	Albatross station 3856.....	♀	.....	319
1	.....do.....	127-128	Albatross station 3857.....	♀	.....	315
1	.....do.....	138-140	Albatross station 3859.....	♀	.....	305
1	Off Mokapu Islet, Molokai.	Surface.	Albatross station 3889.....	♀	.....	312
2	.....do.....	Surface.	.....do.....	juv.	.....	307
1	Auau Channel.....	126-130	Albatross station 3896.....	♂	.....	322
1	Off Kalaupapa, Molokai.....	Surface.	Albatross station 3905.....	♂	U. S. Nat. Mus., Cat. 214380; type.	320
12	.....do.....	Surface.	.....do.....	♂ ♀	Paratypes.....	323
1	21° 13' N. lat., 158° 43' W. long.	Surface.	Albatross station 3926.....	♀	.....	304
2	25° 27' N. lat., 171° 08' W. long.	Surface.	Albatross station 3931.....	juv.	.....	302
6	Between Oahu and Kauai.	Surface.	Albatross station 3980.....	juv.	.....	317
3	.....do.....	Surface.	.....do.....	juv.	.....	300
5	.....do.....	Surface.	Albatross station 4010.....	juv.	.....	310
1	Off Puniawa Point, Maui.	52-56	Albatross station 4071.....	♀	.....	306
1	.....do.....	69-78	Albatross station 4073.....	♀	.....	303
1	Pailolo Channel.....	122-132	Albatross station 4102.....	♀	.....	308
2	.....do.....	122-132	.....do.....	♀	.....	313
1	.....do.....	132-141	Albatross station 4103.....	♂	.....	301
1	Vicinity of Modu Manu.....	Surface.	Albatross station 4152.....	juv.	.....	314
1	.....do.....	Surface.	Albatross station 4153.....	juv.	.....	316
1	Honolulu Reef, Oahu.....	Shore.	Albatross expedition.....	♀	.....	187
1	.....do.....	Shore.	.....do.....	♀	.....	321
9	.....do.....	Shore.	O. P. Jenkins.....	4 ♂ 5 ♀	Stanford Univ. Coll., Cat. 2094.	299
1	Honolulu Market.....	.....	Louis Berndt.....	♂	Stanford Univ. Coll., Cat. 2095.	298
1	Honolulu, Oahu.....	Shore.	.....do.....	♂	Stanford Univ. Coll., Cat. 2096.	297
1	.....do.....	Shore.	.....do.....	1 ♂ 2 ♀	Stanford Univ. Coll., Cat. 2097.	296

Remarks.—The specimens which have been made the subject of the foregoing detailed description do not appear to offer any features in essential disagreement with Grant's brief account of his *Sepiola stenodactyla* from Mauritius, but with the recent more careful description by Hoyle^a of some south Pacific specimens which he referred to Grant's species they are not in complete accord. The observed differences are admittedly trivial, but they maintain themselves persistently and with great constancy throughout the large series of specimens which has been examined and hence seem worthy of recognition. As in the case of most closely related sepiolids the chief difference is in the structure of the hectocotylyzed arm. In Hoyle's figure of *S. stenodactyla* the modified papillæ begin about halfway up the arm. Those of the ventral row are comparatively stout, fairly regular, not very closely appressed, and the figure shows only about fifteen of them. The conspicuous thickening of the arm at the point where the papillæ begin and the strongly recoiled tip exhibited by the Hawaiian specimens do not appear. In *E. scolopes*, moreover, the modified papillæ extend over a much greater proportional area (two-thirds) of the arm, are much more numerous (35 to 40 in the ventral row), and so tightly palisaded together that many of them are squeezed quite out of place. The details regarding the modified suckers of the remaining arms are also different from Hoyle's description, especially in the case of the third pair, where in *E. scolopes* about twice as many of the suckers in the ventral series undergo enlargement. Unfortunately this comparison has been hampered by the lack of actual specimens of *E. stenodactyla* or any other Indo-Malayan representatives of the genus, so that the separate recognition of the Hawaiian race should perhaps be regarded as somewhat provisional.

It is interesting to note that the differences separating the Japanese *E. morsei* from either *stenodactyla* or *scolopes* are not very conspicuously greater than those just dwelt upon, but they appear equally constant, and I regard my original reference of the Hawaiian material to *E. morsei* as clearly erroneous. The males of the last-named species may be distinguished at a glance by the much more conspicuously enlarged suckers of the outer rows on the sessile arms, especially those of the second pair. Apart from secondary sexual characters, however, a description of one species, however detailed, would, so far as I am aware, serve almost equally well for either of the others, and I am at a loss to name any satisfactory criterion for the separation of any of these puzzling forms when represented by females alone.

E. scolopes is one of the most abundant and ubiquitous cephalopods of the Hawaiian Islands. Not only is it a common surface form throughout the surrounding waters but it is to be captured on the reefs and even at considerable depths, as may be seen from the accompanying table. It is, however, a surprisingly constant species, the greatest variation observed being in the general form and proportions of the body, and even this is more probably due to the varying stresses of preservation than to any inherent differences in the animals themselves. It doubtless possesses luminous properties as glandular organs similar to those described by Meyer (1906) for *Sepiola*, and more especially by Wülker (1910, p. 26) for *E. morsei* are very conspicuous in a corresponding position within the mantle cavity.

The specific name *scolopes* has been adopted in reference to the stockade-like appearance of the outer papillæ on the hectocotylyzed arm.

Subfamily STOLOTEUTHINÆ, new subfamily.

Mantle and head united in the nuchal region by a commissure. Suckers in two rows, for the most part very small. Both dorsal arms hectocotylyzed, but the modification weak, consisting chiefly in the greater or smaller size and more crowded condition of the suckers. Eyes with a completely circular lidlike fold. Gladius, none.

Genus STOLOTEUTHIS Verrill 1881.

Stoloteuthis Verrill 1881, p. 417.

Stoloteuthis Verrill 1882, p. 375 [165]

Body short and thick, bluntly rounded behind. Fins large. Arms short; all except the ventral pair united by a wide delicate basal web. Suckers for the most part minute. Mantle ornamented ventrally by a sharply delimited and specially pigmented shield-shaped area of the integument.

Type.—*Sepiola leucoptera* Verrill 1878 (monotypic); a species of the New England region.

^a Hoyle, 1904, p. 24, fig. B-D.

Subgenus IRIDOTEUTHIS Naef 1912.

Iridotheuthis Naef 1912, p. 247.

Body extremely short and rounded; transversely compressed. Nuchal commissure very broad, reaching to a point opposite the anterior margin of the fins. Fins exceedingly large, their basal attachment relatively narrow. Mantle produced far forward ventrally so as to nearly conceal the head and funnel. Head very large, the eyes much swollen and protruding. Arms very unequal; dorsal and second pairs short; third pair considerably longer. Photogenic organs inconspicuous, leaving the greater portion of the ink sac uncovered.

Type.—*Stoloteuthis iris* Berry 1909 (monotypic); described from the Hawaiian Islands.

Stoloteuthis (Iridotheuthis) iris Berry 1909. (Pl. I, fig. 1, 2.)

Stoloteuthis iris Berry 1909, p. 410, 413, fig. 3.

Iridotheuthis iris Naef 1912, p. 247.

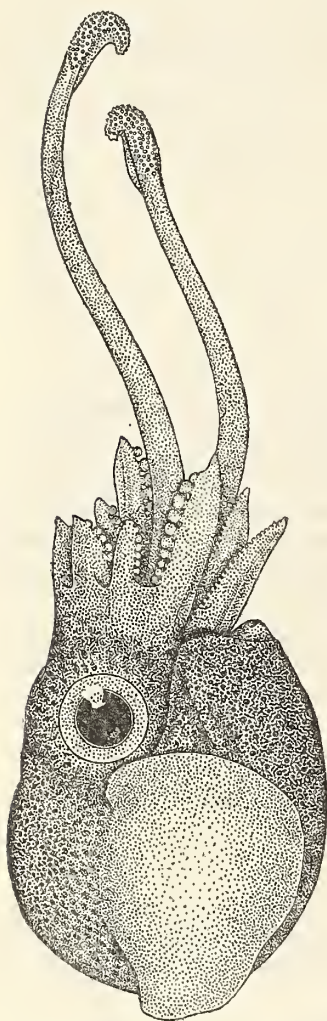


FIG. 27.—*Stoloteuthis iris*, lateral view of type [31]. X 4. Drawn by R. L. Hudson.

Body small, short, stout; much compressed and flattened laterally, rounded very abruptly behind; width and length dorsally about equal and both greatly exceeded by the depth. Mantle smooth, broadly continuous above with the integument of the head from which it is delimited only by a rather prominent cutaneous line or shallow fold; anterior ventral margin produced forward beneath the eyes and far past them to form a broad, deeply convex lobe, which almost entirely conceals the funnel and ventral surface of the head to which its upturned anterior margin is closely applied. A shallow notchlike indentation in the free anterior edge of the lobe permits the tip of the funnel to be seen; convex central region of lobe differentiated from the rest of the mantle surface as a large, slightly raised and flattened, heart-shaped area. Laterally, as in Verrill's *Nectoteuthis*, the mantle margin "recedes in such a way as to leave the large prominent eyes exposed." Fins relatively enormous, thin, their outline rounded oblong to subcircular; much narrowed at the base; slightly broader and conspicuously longer than the body, exceeding it both anteriorly and posteriorly; anterior margin reaching to the eyes, its extremity rounded; posterior margin obtusely pointed; the plane along which the fins are attached is considerably above the median horizontal plane of the body.

Head extremely large; short, wide, flattened. Eyes large, so swollen and protruded in the only specimen at hand that they have lost all appearance of having free lids, perhaps because in pushing outward they have evaginated the usual circular lid fold; they are situated in the angle of the mantle margin above the ventral lobe. Funnel visible only after the removal of the mantle lobe; very broad at base, thence rapidly tapering to a sudden and deep constriction which occurs just in advance of the middle; entire extremity beyond the constriction swollen and thickened; a secondary gland-like swelling occurs on the dorsal external aspect of the funnel in this region, terminating in a very short blunt papilla which fits

in between the true tip of the funnel and the bases of the ventral arms; walls of funnel thick, the interior narrowed and of relatively small capacity; aperture very minute. Funnel organ large, occupying almost the entire interior surface posterior to the median constriction; dorsal cushion with widely flaring lateral wings, almost trilobate in outline; ventro-lateral pads large, wide, and very loosely

adherent. Locking apparatus a slightly curved cartilaginous groove at either side of the base of the funnel with conspicuous ridges to correspond on the inner wall of the mantle considerably posterior to its margin.

Sessile arms short, connected by a well-developed basal web reaching beyond the middle of the dorsal arms, but diminishing ventrally and entirely absent between the ventral pair; conspicuously unequal, the order of length 3, 4, 2, 1; third pair much the stoutest and longest and with somewhat larger suckers than the remainder, also differing in the possession of a prominent membranous keel bordering their outer margins; ventral arms also keeled in somewhat similar fashion, but less prominently. Suckers in two rows on all the arms, crowded; extremely minute, especially on the dorsal and ventral arms; those of the second arms slightly larger, and those on the third pair distinctly the largest of all, although not very conspicuously so (most of the suckers on this pair of arms have been lost through abrasion, so that it can not be determined whether or not any of the more distal ones are subject to enlargement or other special modification; the stumps of the pedicels, however, are entirely similar to one another); individual suckers spherical, with small openings and smooth horny rings; pedicels very short.

Tentacles exceedingly long and slender; tapering; slightly thickened at the base; club but little if any wider than the stalk, velvety in appearance, and under a high power lens seen to be armed with about eight rows (fewer at base) of extremely minute crowded suckers, those near the base somewhat the largest, thence gradually and regularly diminishing in size toward the tip. (Pl. I, fig. 2.)

Ink sac large, by no means covered by the photogenic glands, which, though distinct in the present material, appear to be of small size and very anterior position.

Gladius not observed; probably absent as in *S. leucoptera*.

Color in alcohol for the most part a brownish white; suffused about the eyes, base of the fins, and notably about the ventral shield, with a purplish black; fins unmarked; mantle closely speckled above and below with small brownish chromatophores of two main types, which become rather fewer in number posteriorly and on the sides; those of the one type are paler, larger, more suffused, and more evenly distributed; the others are darker, much smaller, more distinct, and more exclusively confined to certain areas, such as the dorsum and especially the ventral shield, where they are very thickly and evenly distributed; the difference is very apparent, but I am not sure what morphological

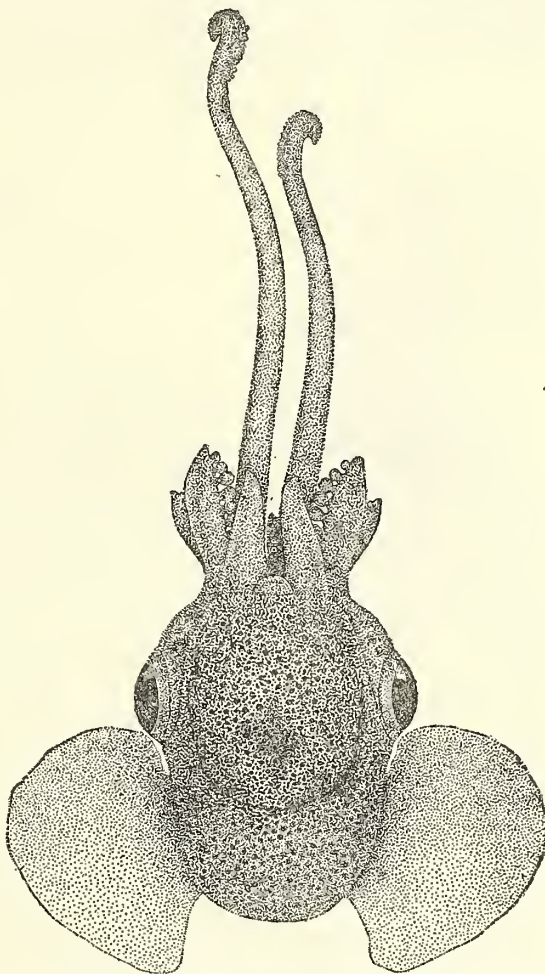


FIG. 28.—*Stoloteuthis iris*, ventral view of type [31], $\times 4$. Drawn by R. L. Hudson.

significance, if any, is possessed by it. The ventral surface is further ornamented by a dark bluish-gray band bordering the heart-shaped shield.

The following note appears on the reverse of the original station label in the handwriting of Dr. W. K. Fisher and affords important information regarding the appearance of this species in life (colors according to Ridgway's "Nomenclature of Color"): "Tentacles, chromatophores burnt sienna, yellow ocher, and light red. Eye: pupil transparent, iridescent purple, blue, and emerald green; iris reddish burnt sienna. Body (except wings and outer test) iridescent orange, yellow, solferino, green, crimson, purple. Chromatophores of outer test burnt sienna and sepia."

MEASUREMENTS OF *STOLOTEUTHIS* (*IRIDOTEUTHIS*) *IRIS*.

	<i>mm.</i>		<i>mm.</i>
Total length exclusive of tentacles.....	16	Length of head.....	4
Medio-dorsal length of mantle.....	7	Width of head.....	8
Medio-ventral length of mantle.....	11	Length of—	
Width of body.....	7	Dorsal arm.....	4
Width across fins.....	18	Second arm.....	5
Extreme length of fin.....	9	Third arm.....	6
Length of same fin at base of attachment.....	4	Ventral arm.....	5
Median length of ventral shield.....	7	Right tentacle (left tentacle missing).....	21
Dorsal-ventral diameter of body.....	10		

Type.—Catalogue No. 214312, United States National Museum [S. S. B. 31].

Type locality.—The type and only specimen of the species known was taken in 153 to 142 fathoms, Albatross station 3832, off the island of Molokai, bottom of brown mud and sand.

Remarks.—The sex of the single specimen is unknown, as owing to the brittle texture of its tissues it was deemed inadvisable to attempt to pry the arms far enough apart to ascertain any further details of structure or possible evidences of hectocotylization. It is very possible that the specimen is not quite adult, but its characteristic features have nevertheless attained a high development.

Perhaps the most distinctive features are the extreme development of the dorsal commissure uniting the mantle to the head, and the immense ventral lobe. The former feature is carried to a much further extreme in this species than in either *S. leucoptera* or in *S. nipponensis*, which are the only other described species of the genus, while in the latter respect the only near approach is the *Nectoteuthis pourtesii* of Verrill. According to information furnished me by Dr. Ad. Naef, *S. nipponensis* differs from the other species mentioned in important anatomical characters, as well as in its size and general aspect, and must henceforth be known as *Sepiolina* Naef. Its exact systematic position still seems a matter of more or less uncertainty, although Naef refers it to the *Sepiolinae*. All three of the remaining species, *S. leucoptera*, *S. iris*, and *N. pourtesii*, are characterized by the possession of a conspicuous pigmented shield on the ventral surface similar to that above described, have large fins, and are delicate gaily colored creatures of doubtless similar habits. *N. pourtesii*, however, stands quite alone in having the dorsal border of the mantle entirely free, and *S. iris* likewise is in many ways very different from its congener. Because of this fact it also has recently been made by Naef the type of a separate genus, *Iridoteuthis*, but because its most important characters (nuchal commissure, ventral shield, webbed arms, etc.) are shared equally with *Stoloteuthis* s. s., I believe their probable relationships are for the present expressed better by grouping them together. The distinctive features adduced by Naef are the integumentary fold in the nuchal region, the large head, protruding eyes, immense fins, ventral protraction of the mantle, and unequal arms, but none of these features seem sufficient of themselves to be regarded as of more than subgeneric value. A more complete knowledge of either *S. iris* or *S. leucoptera* than we at present possess might, however, indicate differently.

Subfamily HETEROTEUTHINÆ Appellöf 1898.

Heteroteuthinæ Appellöf 1898, p. 624.

Heteroteuthinæ Joubin 1902, p. 111.

Heteroteuthinæ Naef 1912, p. 246.

Mantle margin free all around; a cartilaginous articulation in the nuchal region, but the mantle and body fused farther back. Right dorsal arm hectocotylized. Photogenic glands large and conspicuous, nearly covering the ventral surface of the ink sac; closely conjoined along the median line.

Genus HETEROTEUTHIS (Gray 1849).

Rossia (*Heteroteuthis*) Gray 1849, p. 90.

Heteroteuthis Steenstrup 1900, p. 287.

Stephanoteuthis Berry 1909, p. 408.

Heteroteuthis Naef 1912, p. 246.

Body plump, compact; obtusely pointed posteriorly. Fins large, more posterior than anterior in position. Ventral mantle margin produced forward beneath the head so as to almost or even entirely conceal the funnel. Arms short, webbed all around except between the ventral pair. Right dorsal arm hectocotylized and united at base with the second arm of the same side; a few suckers on the third arms of the male greatly enlarged.

Type.—*Sepiola dispar* Rüppell 1844 (monotypic); a species of the Mediterranean region.

Heteroteuthis hawaiiensis (Berry 1909) Naef 1912. (Pl. I, fig. 3-8.)

Stephanoteuthis hawaiiensis Berry 1909, p. 409, fig. 2; p. 418.

Semirossia (?) sp. Berry 1909 p. 418 (merely listed).

Heteroteuthis hawaiiensis Naef 1912, p. 246.

Heteroteuthis hawaiiensis Berry 1912c, p. 645.

Female (type specimen): Body short, plump, compact, very firm and solid; dorsal aspect tapering posteriorly and terminating past the fins in an obtuse point; ventral half of body more rounded, scarcely tapering, and abruptly surpassed above by the pointed dorsal portion, from which it is separated by a short curved horizontal groove, as though the dorsal and ventral halves of the body were slid upon one another beneath the integument like the two divisions of a large bean; dorsum less convex than the venter, which is full and rounded. Mantle margin free all around, sinuous; slightly projecting above, thence sweeping backward, downward, and then far forward again, broadly curving beneath the eyes to form a conspicuous ventral lobe, which, though slightly emarginate in front, entirely conceals both the funnel and the ventral surface of the head. In the nuchal region a little way behind the margin the mantle is united to the body by an indistinct cartilage and a delicate membrane which is easily torn away. Ventral locking apparatus essentially as in other Sepioids; an elongated groove with a raised and reflexed margin articulates on either side of the base of the funnel with a thickened ridge on the inner surface of the mantle, the ridge bent at its anterior end so as to inclose a small pitlike depression. The very tight adhesion of the ventral lobe of the mantle to the head is secured in two ways: First, by the strong upward flexion and close application of the margin to the ventral surface of the head, and, secondly, by the insertion of this margin into two deep curved grooves extending obliquely along the under surface of the head from a point about midway of the lower eyelid, nearly but not quite to the cleft between the ventral arms; on the eyelid the groove is shallowest, deepest at its inner end, and bounded anteriorly by a heavy raised margin. (Pl. I, fig. 7 and 8.)

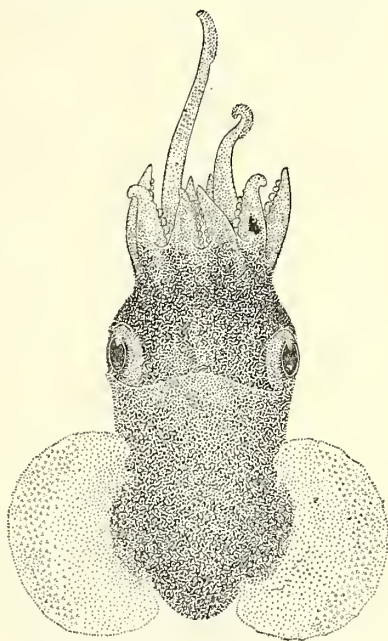


FIG. 29.—*Heteroteuthis hawaiiensis*, dorsal view of type [30], $\times 1\frac{1}{2}$. Drawn by R. L. Hudson.

Head very large, due to the large rounded eyes; broader than the body; flattened above, much excavated beneath. Eyes prominent, with large white pupils and a very deep ventral lid fold. Funnel very stout and thick; flattened; outline bluntly conical; extremity rounded; aperture small.

Sessile arms short, stout, thick; unequal, the order of length 3, 4, 2, 1; dorsal pair shortest, third pair longest,^a but the ventral almost as long as the third and even longer if measured along the cleft separating their inner ventral margins; connected at base by a fleshy umbrella, best developed between the dorsal arms, between these and the second pair, and between the third pair and the ventral pair; between the second and third arms the web is very short, and is totally lacking between the arms of the ventral pair, which are divided from one another by a deep cleft extending as far back as the tip of the

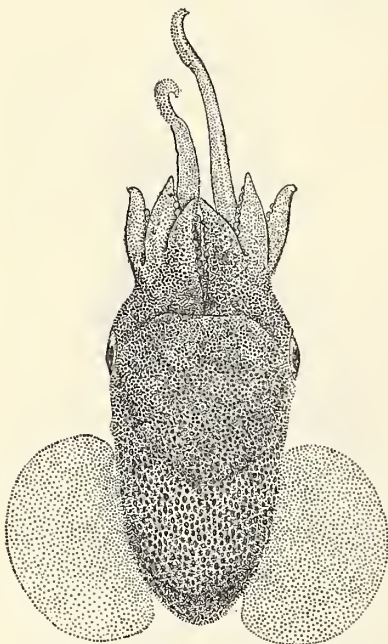


FIG. 30.—*Heteroteuthis hawaiiensis*, ventral view of type [30], $\times 1\frac{1}{2}$. Drawn by R. L. Hudson.

conspicuous as the corresponding region of *Stoloteuthis* and was hence overlooked by the artist when the first drawings were made (pl. I, fig. 7). Chromatophores appear also upon the ventral aspect of the head and funnel, even extending upon the dorsal surface of the latter, but are not to be distinguished upon the tentacles.

Gladius apparently wanting.

funnel; second arms rounded, the remainder with a distinct keel along their outer margins distal to the webbed portion. Suckers small, spherical, oblique; in two rows extending nearly or quite to the tips of the third arms, but leaving the final distal extremities of all the other arms bare; this circumstance becomes especially conspicuous in the case of the second pair, where the distal portion of the arm is not only devoid of suckers, but is minutely ridged transversely and exhibits a strong tendency to recoil upon itself (pl. I, fig. 5); horny rings of suckers smooth.

Tentacles rather short, stout, angled, slightly tapering, with a flattened and somewhat grooved out inner surface. Club small, of considerably less diameter than the stalk; inner aspect with a velvety appearance, due to the great multitude of exceedingly minute suckers with which it is armed (pl. I, fig. 3).

Surface everywhere smooth.

Color of the living animal unknown; in alcohol a brownish buff; fins and arm tips unmarked; dorsum and head heavily dotted and clouded with the blackish chromatophores which appear as open reticulations about the bases of the fins; ventral surface of mantle less densely pigmented, except for a shield-shaped area occupying the ventral lobe and extending back therefrom, over which the chromatophores are very numerous and distinct, being apparently of two main sizes, somewhat as noted in the case of *Stoloteuthis iris*; the marginal delimitation of this area is by no means so distinct and

MEASUREMENTS OF *HETEROTEUTHIS HAWAIIENSIS*.

	mm.		mm.
Total length, exclusive of tentacles.....	38	Width between eyes.....	10
Medio-dorsal length of mantle.....	22	Length of—	
Medio-ventral length of mantle.....	27	Dorsal arms.....	8
Width of body.....	14	Second arms.....	9
Width across fins.....	32.5	Third arms.....	10
Extreme length of fins.....	17	Ventral arms.....	9-12
Length of fins at base of attachment.....	9.5	Tentacle.....	21
Anterior mantle margin to base of dorsal arms.....	8.5		

^a Owing to an inadvertence the original description states the reverse to be true.

In addition to the specimen above described, the *Albatross* collection contains three other individuals which are so badly macerated (as though taken from the digestive cavities of larger animals, as was undoubtedly the case) that their true identity was not ascertained for a considerable length of time. One of these is a male and has been made the subject of the following notes:

Male: Third arm pair very much larger than the others, bearing two or more very greatly enlarged basin-shaped suckers (pl. I, fig. 4) at their distal ends. No evidence of hectocotylization visible except that the left dorsal arm is much smaller than the right and is closely united with its neighbor of the second pair by a very narrow basal webbing; no true fusion of the arms on either side can be made out after the fashion described for *H. dispar*.

The firm adherence of the mantle and body just back of the nuchal cartilage is very clearly evident in this specimen.

The extremely desiccated condition of the specimen precludes the giving of more accurate or complete details.

Type.—Catalogue No. 214311, United States National Museum [S. S. B. 30].

Type locality.—*Albatross* station 3989, 733 to 385 fathoms depth, in the vicinity of the island of Kauai, coral sand and rock bottom, June 11, 1902; 1 ♀.

Distribution.—Vicinity of the Hawaiian Islands (*Albatross*).

SPECIMENS OF *HETEROTEUTHIS HAWAIIENSIS* EXAMINED.

No. of specimens.	Locality.	Depth in fathoms.	Collector.	Sex.	Remarks.	Author's register.
1	Vicinity of Kauai.....	385-733	Albatross station 3989.....	♀	U. S. Nat. Mus.; type, Cat. 214311.	30
1	Pailolo Channel.....	280-283	Albatross station 3900.....	♀	Fragmentary.....	34
1	.....do.....	297-306	Albatross station 4088.....	♂	.....do.....	33
1	.....do.....	297-304	Albatross station 4089.....	?	.....do.....	333

Remarks.—The only other species of this genus which are at present recognized are the *H. dispar* (Rüppell) of the Mediterranean region and *H. weberi* Joubin from the Dutch East Indies, from each of which *H. hawaiiensis* appears clearly distinct. Its nearer relationships are certainly with *H. dispar*, but it is to be differentiated on the following grounds:

1. Indications of the presence of a ventral shield similar to that already familiar in *Nectoteuthis* and *Stoloteuthis*, but much less clearly defined.
2. The complete concealment of the funnel by the ventral lobe of the mantle.
3. The heavy oblique folds on the under surface of the head which apparently function to secure a more perfect application of the mantle margin to the head and thus serve as a secondary locking apparatus.
4. The curious nonconformity between the dorsal and ventral halves of the body in mature females.
5. The shorter arms.

The adults of this species are very neat, compact little creatures of pleasing appearance, and like all their near allies are probably quite brilliantly colored when living. They also possess luminous properties, the photogenic glands overlying the ink sac in the present species being in all respects closely similar to those described for *H. dispar* and very conspicuous even in the macerated specimens.

DIVISION ŒGOPSIDA (d'Orbigny 1845).

Decapoda Œgopsidæ d'Orbigny 1845, p. 367.

Chondrophora Gray (pars) 1849, p. 36, 37.

Œgopsidæ Kieferstein 1866, p. 1444.

Œgopsidæ Verrill 1881, p. 427.

Œgopsidæ Hoyle 1886, p. 32, 162.

Œgopsidæ Pfeffer 1900, p. 151.

Œgopsidæ Chun 1910, p. 3.

Œgopsidæ Pfeffer 1912, p. 1.

Eyelids perforate over the cornea; their margins free all around and continuous except for the usual presence of a notch or sinus in front. Suckers on either the sessile arms or tentacles or both frequently

transformed into hooks. Complex photogenic organs of polymorphic structure and undoubtedly polyphyletic origin are of repeated occurrence.

Family ONYCHOTEUTHIDÆ Gray 1849.

Onychoteuthidæ Gray 1849, p. 36, 45.

Onychoteuthidæ Pfeffer 1900, p. 152, 154; 1908, p. 62, 63; 1912, p. 39.

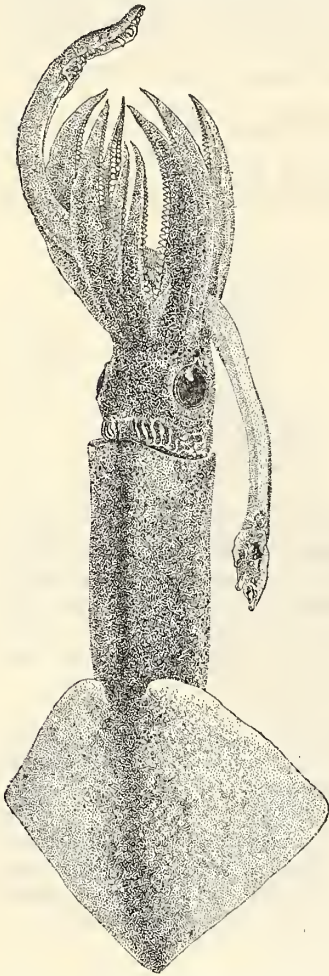


FIG. 31.—*Onychoteuthis banksii*, oblique dorsal view of specimen [227] from near Laysan Island, $\times \frac{1}{2}$. Drawn by R. L. Hudson.

Arms moderate, stout, outwardly keeled; armed with two rows of small oblique hood-shaped suckers, produced at the upper margin. Tentacles long and stout, the club not expanded except for

Animals of small to gigantic size; body stout, loliginiform. Suckers on sessile arms in two rows and normal throughout. Tentacle club with part of the suckers unmodified, the remainder transformed into hooks; fixing apparatus a compact carpal group of suckers and pads.

Genus ONYCHOTEUTHIS Lichtenstein 1818.

Onychoteuthis Lichtenstein 1818, p. 1591 (*vide* Hoyle); 1818a, p. 223.

Onychoteuthis d'Orbigny 1845, p. 383.

Onychoteuthis Pfeffer 1900, p. 156, 158; 1908, p. 64; 1912, p. 70.

Body of moderate size, cylindrical, tapering. Fins broadly sagittate. Head with a conspicuous "olfactory crest" made up of series of broad longitudinal lamellæ. Arms stout, bearing true suckers only. Tentacles stout, the clubs armed with two rows of hooks on the central part; fixing apparatus a very definite compact rounded group of small suckers and pads on the carpus. No hectocotylization. Gladius narrow and slender, showing through the integument as a well-defined dark streak; a small spoon-shaped cone at the posterior extremity. Hoyle has recently discovered the existence of photogenic organs within the mantle cavity.

Type.—*Onychoteuthis Bergii* Lichtenstein 1818=*O. banksii* (Leach 1817), a cosmopolitan species.

Onychoteuthis banksii (Leach 1817) Férussac 1826.

Loligo Banksii Leach 1817, p. 141.

Onychoteuthis Banksii Férussac in d'Orbigny 1826, p. 151.

Onychoteuthis Banksii d'Orbigny 1845, p. 386, pl. 26, figs. 1-7.

Onychoteuthis Banksii Schauinsland 1899, p. 92 (locality record).

Onychoteuthis Banksii Pfeffer 1912, p. 70, 758, pl. 3, fig. 13-25, pls. 4-6.

Onychoteuthis banksii Berry 1912, p. 83, figs. 44-46.

This is such an abundant and universal species that I have given above only some of the more particularly relevant references regarding it. For similar reasons the following description is made only complete enough to afford sufficient means for its ready identification.

Body of moderate size, loliginiform, with a pair of large broadly sagittate fins extending a little more than half the length of the mantle. Head small, squarish; ornamented just below the nuchal region with a conspicuous series of about a dozen stout longitudinal lamellæ on either side. Eyes large, with capacious openings.

the broad marginal membrane; armed with two rows of 9 to 12 hooks each, those of the ventral row in the main conspicuously the larger. Fixing apparatus a compact rounded group of suckers and pads in approximately equal numbers on the carpus. There is a compact cluster of minute suckers at the tip of the club.

Color in alcohol a brownish buff, mottled with slate; a very irregular dark streak on the dorsal aspect marks the position of the gladius.

MEASUREMENTS OF *ONYCHOTEUTHIS BANKSII*.

	mm.	Length of—	mm.
Total length.....	315	Right second arm.....	69
Tip of body to dorsal margin of mantle.....	150	Left second arm.....	69
Width of mantle.....	33	Right third arm.....	71
Width across fins.....	112	Left third arm.....	68
Extreme length of fins.....	87	Right ventral arm.....	70
Length of fins at plane of attachment.....	80	Left ventral arm.....	43+
Length of head.....	16	Right tentacle.....	141
Width across eyes.....	30	Right tentacle club.....	34
Length of—		Left tentacle.....	125+
Right dorsal arm.....	57	Left tentacle club.....	27+
Left dorsal arm.....	54	Carpal fixing apparatus.....	5

Distribution.—"Distribution nearly universal; collected in all the oceans at numerous localities, equally in Arctic and tropical waters." (Tryon 1879, p. 168.)

Neighborhood of Laysan Island (Schauinsland; Stanford University collection).

Material examined.—But a single Hawaiian specimen of this species has been examined. This is no. 2101 of the Stanford University invertebrate series and was taken off Laysan Island by Mr. Max Schlimmer [S. S. B. 227].

Remarks.—I can not find that this Laysan Island specimen exhibits any particular differences from the *O. banksii* I have seen from the Atlantic and elsewhere. So far as can be determined, there appear to have been 11 hooks in each row on the right tentacle club and more than likely on the mutilated left tentacle as well. The fixing apparatus of each tentacle contains 10 suckers and an exactly equal number of pads, a feature which appears to be subject to great variation in this species.

It seems clear that the original spelling of the specific name was the result of an accidental transposition of type, so that the emended version seems preferable. *O. banskii*, *O. banski*, *O. banksii*, and *O. banksi* are abundantly appearing variants in the extensive literature.

This is one of the species of squid preyed upon by the Laysan albatross, and has been previously reported in this connection by Schauinsland.

Genus *TELEOTEUTHIS* Verrill 1882.

Onykia Lesueur 1821, p. 98.

Onykia Lesueur 1822, p. 296.

Onychia Latreille 1825 (*vide* Gray), not *Onychia* Hubner 1816.

Teleoteuthis Verrill 1882, p. 279, 280.

Teleoteuthis Pfeffer 1900, p. 155, 156; 1912, p. 42, 43.

Animals of small or very moderate dimensions. Tentacle club of young with four rows of suckers, the two median of which become typically modified into hooks in the adult, but in some cases only one of the median rows is noticeably modified, and one of the marginal rows is often very weakly developed. Gladius with broad wings as in *Loligo*.

Type.—*Onykia Carriboea* Lesueur 1821 (species first named); a widespread species originally described from the West Indies.

Teleoteuthis compacta Berry 1913. (Pl. LII, fig. 4, 5.)*Teleoteuthis appellöfi* Berry 1909, p. 419 (locality record only), not of Pfeffer 1900.*Teleoteuthis compacta* Berry 1913, p. 565.

Animal small, loliginiform. Mantle almost cylindrical anteriorly; slightly swollen a little in advance of the middle, thence tapering rapidly to a very acute point. Fins enormous, broadly sagittate in outline, their total width about equal to the length of the mantle; length a little more than

half that of the mantle. Mantle margin slightly produced in the medio-dorsal line to form an obtuse point, and a little more prominently in the same way on either side of the funnel; emarginate below the funnel.

Head squarish, narrower than the mantle, into which it may be almost completely withdrawn. Eyes little prominent; their lid openings small, notched in front.

Arms short, stout, little attenuate; unequal, their order of length 3, 2, 4, 1; the dorsal arms clearly shorter than those of the second and third pairs. Suckers on all the arms small, rotund, closely ranked in two widely interspaced series. (Pl. LII, fig. 5). Umbrella wanting, but all the arms well angled, and the third pair furnished externally with a strong membranous keel.

Tentacles short, stout, but little exceeding the arms; clubs not thickened, but broadly keeled above and slightly so along the ventral margin; both suckers and hooks present on the club; hooks sessile, 10 to 11 in number and in a single longitudinal series, comprising the more ventral of the two median rows of acetabula; first five hooks quite small, the next three much larger, the distal ones diminishing again; the two dorsal rows of suckers irregular, the first five pairs small and

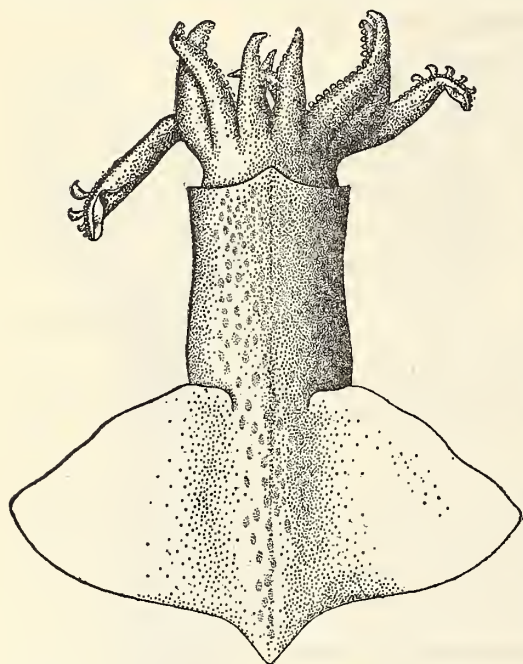


FIG. 32.—*Teleoteuthis compacta*, dorsal view of type [238], $\times 3$.

closely placed, the succeeding ones slightly larger and more distant, becoming smaller again distally; the suckers of the inner dorsal row persist in alternation with the hooks to the tip of the club, but the marginal row becomes obsolete distally and comprises only about eight suckers in all; suckers of the ventral row exceedingly minute, especially distally where they are placed very far apart. The extreme tip of the tentacle is occupied by a group of excessively minute suckers, which are scarcely visible as such with an ordinary hand lens. Fixing apparatus well developed, comprising a quadruple series of small suckers and pads in alternation; about 8 pads and 12 suckers can be made out. (Pl. LII, fig. 4.)

Gladius delicate, the expanded wings greatly narrowing in front of the hollow terminal cone.

Color in alcohol a brownish buff. Chromatophores light brown, scarcely visible below.

MEASUREMENTS OF *TELEOTEUTHIS COMPACTA*.

	mm.	Length of—	mm.
Total length including tentacles.....	28	Dorsal arms.....	4.5
Tip of body to dorsal mantle margin.....	21	Second arms.....	5.5
Width of body.....	6	Third arms.....	6
Width across fins.....	20	Ventral arms.....	5
Extreme length of fins.....	12	Left tentacle.....	7
Length of fins at base.....	11	Tentacle club.....	3.5
Width across eyes.....	5		

Type.—Catalogue No. 214381, United States National Museum [S. S. B. 238].

Type locality.—*Albatross* station 3989, 385 to 733 fathoms, vicinity of Kauai Island, coral, sand and rock bottom, June 11, 1902; one specimen.

Distribution.—Hawaiian Islands (*Albatross*).

Specimens examined.—The type is unique.

Remarks.—It was at first thought that this specimen might be referable to the *T. appellöfi* of Pfeffer and was indeed so listed in a preliminary paper, but a more careful study of details, particularly those of the tentacular armature, has convinced me that the present species is distinct and stands rather nearer to M. Joubin's *T. caroli* (1900, p. 64), from which it differs in the relatively larger fins and shorter and differently armed tentacle club.

The latter structure is a curious affair and is better to be understood from the figure than from my description. It offers several apparent divergencies from that of *T. caroli* as figured by Joubin (1900, pl. 11, fig. 10), especially in the fixing apparatus, for *T. caroli* is represented as having but seven suckers (pads are omitted from the drawing but mentioned in the text). Furthermore, the suckers of the club itself are very different in number and arrangement, although the two forms agree in the presence of but a single series of hooks.^a In *T. caroli* the fifth hook from the base attains the maximal proportions, while in our species it is the sixth, and the change in size at this point is conspicuously more abrupt.

It is, however, not at all impossible that the single row of hooks and the broad fins are juvenile characters, the former being intermediate between the hookless condition described by Pfeffer as *Steenstrupiola* (cf. Pfeffer 1900, p. 156) and the normal adult, in which case the Hawaiian specimen may after all prove to be closer to the *T. peratoptera* d'Orbigny, a Chilean species which was indeed originally figured with three rows of suckers and but one series of hooks (d'Orbigny 1835, pl. 3, fig. 6), though since united by d'Orbigny himself with the *T. platyptera* of the same region.

T. appellöfi has fins of somewhat similar proportions, but the structure of the tentacle club is totally different.

Family ENOPLOTEUTHIDÆ Pfeffer 1900.

Enoploteuthidæ Pfeffer 1900, p. 152, 163.

Enoploteuthidæ Chun 1910, p. 52.

Enoploteuthidæ Pfeffer 1912, p. 118.

Animals of small to moderate size. Arms with two rows of suckers, part of which typically are modified into hooks. Tentacles with clubs little or not at all expanded; their suckers in four rows (one or more of these often suppressed in the adult) and usually part of them transformed into hooks; a carpal fixing apparatus present comprising a few suckers and pads. Buccal membrane eight-pointed. Gladius feather-shaped; with broad somewhat angular wings and no end cone. Photogenic organs are almost invariably present on the ventral aspect of the eyeball, and in addition may occur within the mantle cavity or scattered over the ventral surface of the outer integument.

Subfamily ENOPLOTEUTHINÆ (Chun 1910) Pfeffer 1912.

Enoplomorphæ Chun 1908, p. 86.

Enoploteuthinæ Tribus *Enoplomorphæ* Chun 1910, p. 56, 78.

Enoploteuthinæ Pfeffer 1912, p. 124, 125.

Body more or less pointed posteriorly but not spitlike. Fins large and usually sagittate. Buccal membrane free; dorsal lappets well separated. Photogenic organs occur, often in large numbers, on the ventral aspect of the mantle and usually the head and arms as well; in most genera a conspicuous single series of large organs is found on the ventral periphery of the eyeball; no luminous organs in the pallial chamber.

^a Joubin (op. cit., p. 65) states that the hooks of *T. caroli* are in two rows, but it seems to me that the "première série" described as "très petits, longuement pédonculés" are better interpreted as suckers as I have done.

Genus ABRALIA Gray 1849.

Abralia Gray 1849, p. 46, 50.*Abralia* Pfeffer 1900, p. 166, 167.*Asteroteuthis* Pfeffer 1908a, p. 292.*Abralia* Chun 1910, p. 57.*Asteroteuthis* Pfeffer 1912, p. 124, 128.*Abralia* Pfeffer 1912, p. 762.

Fins large, sagittate; more or less pointed posteriorly, and not exceeded by the tip of the pointed body. Arms with two rows of hooks throughout the greater part of their length, but with true suckers at their tips; extremities of ventral arms normal. Left ventral arm hectocotylized. Dorsal row of suckers on proximal portion of tentacle club suppressed in adult, leaving one row of hooks and two rows of suckers which give way to four rows of suckers distally. Buccal membrane in preserved specimens pale and scattered over with reddish chromatophores.

Type.—*Onychoteuthis armata* Quoy and Gaimard 1832 (species first mentioned); described from near the island of Celebes.

Abralia astrosticta* Berry 1909. (Pl. LI.)Abralia astrosticta* Berry 1909, p. 412, 419, fig. 4-7.*Abralia astrosticta* Weindl 1912, p. 271-275.*Abralia* (*Compsoteuthis*) *astrosticta* Pfeffer 1912, p. 149, 151, 163.

Animal of small size. Mantle firm, fleshy, cylindrical in shape, little compressed; tapering at first gradually, then more abruptly to a bluntish point posteriorly. Anterior edge of mantle smooth, emarginate below the funnel, and with a very slight obtuse medio-dorsal angle. Fins moderately large and very wide in proportion to their length; about one-third as long as the mantle, and each one about as broad as long; subterminal, triangular; attached firmly along the inner margin for most of their length; anterior lobes prominent, but posterior margins nearly straight and converging at a very obtuse angle.

Head rather large, but decidedly narrower than the body, squarish, flattened above and below; "olfactory crest" comprising a series of four oblique fleshy folds behind the eye on either side. Eyes large; the circular lid opening with a minute rounded sinus in front. Funnel large, subtriangular, very firm and thick-walled, its center rounded and conspicuously swollen ventrally. Funnel organ well developed, posterior in position; comprising a V-shaped median pad on the interior dorsal wall, and a small elongate-ovate pad placed ventro-laterally to it on either side. The tip of the funnel is furnished with a wide shallow flaplike valve. (Pl. LI, fig. 8.)

On its inner surface the edge of the mantle articulates with the head in the nuchal region and with the base of the funnel on either side by cartilages of the form usual in the genus. The dorsal apparatus consists of a simple longitudinal ridge on the mantle and a corresponding plate on the neck. The funnel cartilages are elongate, slightly widest near the base, have a thickened, raised and reflexed margin, and their grooves are simple, narrow, deep, and elongate (pl. LI, fig. 7); they fit over a slender linear ridge on either side of the inner surface of the mantle.

Sessile arms stout, little attenuate; nearly of a length, but the second arms slightly the longest and stoutest, and the dorsal pair a little shorter and more slender than the others, so that the formula of their relative length is in general 2, 4, 3, 1; outer edge of arms angled and furnished with a keel, membranous and poorly developed on the four dorsal arms, but increased to a fleshy carina on the arms of the third pair and more particularly along the outer aspect of the ventral arms, where it is so heavy and conspicuous as to cause these arms to appear almost twice their true diameter when viewed ventrally. For the greater part of their length all the arms are armed with two widely spaced alternating rows of small hooks which are replaced on the extreme distal portions by a double series of minute crowded suckers; the tips of the ventral arms bear suckers similar to those of the other arms and are indeed entirely normal in every particular; the number of pairs of hooks on the ventral arms is about eight.

Tentacles slender, over half as long again as the arms, cylindrical, little tapering. Club but little expanded, armed with four rows of acetabulæ which respectively may be described as follows: (1) On the distal half of the club all four rows consist of small suckers of about equal size at any given transection

of the arm, but regularly diminishing to the tip; (2) the two dorsalmost rows continue down the club proximally for its entire length, attaining their maximum dimensions near the middle; the two ventral rows on the other hand abruptly cease and are replaced on the proximal half of the club by (3) a single series of five rather large hooks which stand opposite the five proximal pairs of suckers in the dorsal rows; (4) at the base of the club, upon the carpus, is a very definite fixing apparatus comprising a double row of some four to five suckers alternating with a similar number of small whitish pads. (Pl. LI, fig. 2, 6.)

Buccal membrane eight-pointed (as correctly surmised by Pfeffer, my original assertion that there are but seven lappets is erroneous); coarsely papillose within.

Photophores of the outer integument exceedingly numerous and readily perceivable to be in two main sizes, the grouping of the larger of which is distinctly bilaterally symmetrical and varies on different regions of the body as follows:

(1) On the ventral aspect of the mantle appear about ten rather ill-defined longitudinal series of these organs, including (*a*) two nearly median rows of relatively large organs extending without interruption from the anterior mantle margin to the posterior extremity; (*b*) two similar series succeeded laterally by two or three others, composed of organs constantly diminishing both in size and number, occur parallel to these anteriorly, but all converge posteriorly in such a way that in addition to the two central series but one other row persists on each side to the tip. The organs of the various series are very regularly and equally interspaced so that there is a certain tendency evident for the grouping to occur in a transverse as well as a longitudinal direction. Aside from the effect which might well be expected to result from such a tendency, no specially definite line of photophores is found bordering the margin of the pallial aperture. The smaller organs are much more numerous than the larger and occur scattered between and among them in a much more irregular fashion. On the dorsal surface of the mantle photogenic organs are almost entirely wanting, but there is a fairly regular series of about seven small distant organs close to the median longitudinal line on either side, and some distance lateral to these a few (3 to 4) isolated organs, perhaps representing the rudiments or forerunners of other longitudinal series.

(2) The ventral aspect of the funnel exhibits a little in front of its middle a transverse line of four large organs of equal size, in front of and behind which occur a number of smaller ones in such a way as to form four longitudinal series containing one of the large organs and two to three of the smaller ones each. A few scattered organs occur in addition, but all are bilaterally arranged. A clear space down the center of the funnel separates the photophores of each side into two triangular patches. This space, like the extreme tip of the funnel, is colorless and devoid of organs.

(3) There are no photophores upon the upper surface of the head, but upon the lower aspect they appear with perfect symmetry in five longitudinal rows with an additional series bordering each ocular aperture. Here also the larger organs are relatively few in number compared with the smaller, there being only two of the former in the median row, and two to three in each of the lateral series. The median row bifurcates at the apex of the funnel groove (one large organ on either side), and also anteriorly, where either branch parallels a continuation of the first lateral series along each ventral arm to its extremity. The outer lateral series continues for a distance along the border of the membranous keel, so that the basal half of each ventral arm bears in all three rows of photophores. The arms of the third pair have a series of these organs near the base along their ventral aspect, and there are evidences of a second row of smaller ones along the dorsal margin as well. No such structures have been identified upon any of the other arms or upon the tentacles.

All of the photophores appear as minute, but definite, faintly elevated, circular, bluish rings, surrounding a white dotlike center, and having much the appearance of minute eyes. The bluish rings are relatively heavier and more conspicuous in the larger organs, while the smaller organs are by this means again separable into two types, the one much less heavily pigmented than the other.

In addition to photogenic organs of the general type described above, there are to be observed a very conspicuous series of five large reddish bead-like structures upon the ventral periphery of each eyeball. They are placed very close together, are of circular outline and subequal in size (pl. LI, fig. 3). The two terminal organs are considerably lighter in color than the three median ones.

Prevailing color of animal preserved in alcohol, a pale buff brown; the gladius showing through the dorsal integument as a very prominent medio-longitudinal line. Chromatophores brownish; most numerous on the upper surface of the head, which is thus rendered very dark in color; much less numerous on the dorsal aspect of the mantle and below largely replaced by the bluish photophores which are strongly contrasted with the chromatophores in color. Buccal membrane almost uniformly pale, with only a few scattered chromatophores.

Gladius with a thickened midrib; wings unthickened, very delicate, and with distinctly angular margins.

MEASUREMENTS OF *ABRALIA ASTROSTICTA*.

	mm.	Length of—	mm.
Total length.....	65	Left dorsal arm.....	11
Length exclusive of tentacles.....	56.5	Right second arm.....	13
Length of mantle, dorsal.....	34	Left second arm.....	15
Extreme length of fins.....	11	Right third arm.....	12
Length of fins at base.....	9	Left third arm.....	12
Width across fins.....	22	Right ventral arm.....	13
Width of mantle.....	10	Left ventral arm.....	13.5
Width of head.....	9	Tentacle.....	23
Length of—		Tentacle club.....	4
Head.....	8	Funnel.....	6.5
Right dorsal arm.....	11		

Type.—A female; catalogue No. 214313, United States National Museum [S. S. B. 171].

Type locality.—Albatross station 4122, 192 to 352 fathoms depth, off Barbers Point Light, Oahu, bottom of coarse coral sand and shell, July 26, 1902; one ♀ specimen.

Distribution.—Hawaiian Islands (*Albatross*).

Material examined.—No other specimens than the type are known.

Remarks.—This very beautiful little squid is a member of a rare and exceedingly curious group of cephalopods which have been sparsely taken at divers times and in many widely separated localities, and the interrelationships of which are by no means as yet clearly understood. They are *Enoploteuthis* chiefly characterized by the double row of hooks on the arms supplanted distally by suckers, and the extensive development of photogenic organs over the entire ventral surface of the head and body, though not within the mantle cavity, as in the case of certain forms similar to some which will be described later. The peculiar features of the group were first recognized (although only partially) by Gray, who in 1849 founded the genus *Abralia* for their reception. Many years later (Joubin 1896) a second genus, *Abraliopsis*, was erected for the reception of certain *Abralia*-like forms, unique in the possession of a conspicuous series of pigmented swellings at the tips of the ventral arms, and further distinguished by the deep violet color of the buccal membrane, somewhat different structure of the tentacle club, bilaterally symmetrical arrangement of the photophores, and the presence of three instead of two series of these organs upon the ventral arms. A few years ago Pfeffer, on the supposition that the type species of Gray (*A. armata* Quoy and Gaimard) would be found congeneric with *Abraliopsis*, replaced that term by *Abralia* and advanced the new name *Asteroteuthis* for the group thus left without a cognomen. More recently, however, he has once more returned to the older and more familiar arrangement, for upon examination the type specimen of *A. armata* proved that species to be after all an *Asteroteuthis* or true *Abralia* in the accepted sense.

The position of the Hawaiian species now under consideration is in many respects anomalous. Since the tips of the ventral arms are entirely normal, bear suckers at their extremities, and lack all indications of terminal pigmented organs, it is most decidedly not an *Abraliopsis* and Pfeffer's suggestion that the specimen represents a very large *Compsoteuthis* stage of that genus is quite untenable. This is further borne out by the fact that the buccal membrane is not deep violet in color, but pale and dotted with chromatophores, while the main features of the armature of the tentacle club are those of a typical *Abralia*. On the other hand no previously described *Abralia* shows so strikingly symmetrical an arrangement of the photogenic organs on the mantle, or possesses more than two series of these structures on the ventral arms, or has such extremely short and wide fins. In almost every respect, therefore,

A. astrosticta is a remarkably distinct species and is not closely approached by any other known form excepting possibly the very recently described *A. steindachneri* Weindl 1912 of the Red Sea, which is thought by its author to be somewhat nearly related. A complete account of the latter species has not yet reached me, but from the preliminary notice above cited it would seem that this is the case, although the two forms differ in enough particulars to be sufficiently distinct. In Weindl's species the fins are not quite so short and wide, there are seven to eight hooks on the tentacle club, and the median photophore on the eyeball is said to be much the smallest.

It has seemed worth while to make the account of this species as full as possible, firstly on account of the special interest attaching to forms of this group, and secondly because of the unusually fine condition of the present specimen which renders the chance for misinterpretation correspondingly slight.

***Abrealia trigonura* Berry 1913.**

Abrealia species Berry 1909, p. 419 (locality record only).

Abrealia trigonura Berry 1913, p. 565.

There is a second specimen of *Abrealia* in the *Albatross* collection, which, although not very well preserved, is clearly not referable to *A. astrosticta*, but belongs rather to the typical section of the genus.

Animal of small size, in general loliginiform, but the mantle rather short, wide, inflated, and rapidly tapering to a point posteriorly. Fins large, a little over half as long as the mantle; their total width about approximates the length of the mantle.

Head rather small, squarish; olfactory crests low (crushed, and not distinct). Eyes large and prominent. Funnel large, triangular, compressed. Funnel organ well developed; similar in general arrangement to that of *A. astrosticta*, except that the lobes of the median (dorsal) pad are broader, and the ventro-lateral cushions are ovate and conspicuously larger (fig. 33). The funnel has a delicate foldlike valve at the tip.

Arms quite long, over two-thirds the length of the body; sub-equal, but the dorsal pair distinctly the shortest; order of length in general 2, 4, 3, 1. The arms bear two rows of small alternating hooks, which are replaced by suckers at the extremities.

Tentacles very long and slender, the clubs little expanded. The armature is almost entirely effaced, but a single hook persisting on one of the clubs is much longer, more slender, and much more curved than those of *A. astrosticta*.

Buccal membrane large; eight-pointed; papillose and uniformly pale within; its outer surface conspicuously dotted with many small, distinct, dark reddish chromatophores.

The gladius as compared with that of *A. astrosticta* is similar in general shape, but is relatively much flatter and less slender, with, however, a wider and more robust midrib; the lateral expansions are conspicuously broader and their angles more pronounced and more anterior in position.

The photophores of the ventral integument are of a very different aspect than those of *A. astrosticta*, but here also they are apparently of two main types. The larger appear as small whitish tubercles, which, under the microscope, show a lenslike core of chalky white color inclosed by a pale bluish gray ring. The smaller organs are either (1) conspicuously darker, comprising a light bluish core surrounded by a narrow dark ring distinctly composed of separate bodies of pigment, or (2) but slightly darker and resembling the large organs in miniature. The integument of the mantle has mainly sloughed away, but from the portions remaining there appear to have been two very definite parallel rows of the larger organs running down the medio-ventral line, with at least two other series on either side more or less parallel to them. The smaller organs are exceedingly numerous and heavily distributed among the larger all over the ventral surface.

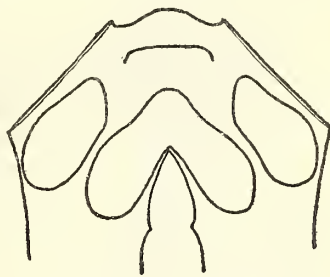


FIG. 33.—*Abrealia trigonura*, outline drawing of funnel organ [275], $\times 3$.

The funnel shows two large triangular groups of numerous organs symmetrically disposed. As in *A. astrodicta* four of these only are of the larger type, but in this species they do not lie in a single transverse line. The tip of the funnel is colorless and devoid of photophores. The number of these organs on the head and arms is no longer to be made out.

Subocular organs are present, but the eyes are so damaged that their exact number and position can not be made out with certainty. They appear, however, to be relatively small and distant from one another.

Color everywhere a brownish buff, heavily clouded with dark reddish chromatophores which are numerous even over the ventral surface. These combine with the bluish photophores to give a purplish cast to the entire animal.

MEASUREMENTS OF ABRALIA TRIGONURA.

	mm.	Length of—	mm.
Total length.....	93	Head.....	11
Length excluding tentacles.....	68	Dorsal arm.....	18
Length of mantle, dorsal.....	28.5	Second arm.....	22
Extreme length of fins.....	17	Third arm.....	20
Length of fins at base.....	15	Ventral arm.....	21
Width across fins.....	29	Tentacle.....	49
Width of mantle.....	13	Tentacle club.....	8?
Width of head.....	11	Funnel.....	9

Type.—Catalogue no. 214387, United States National Museum [S. S. B. 275].

Type locality.—Albatross station 4087, 306 to 308 fathoms, off Mokuhooniki Islet, northeast entrance to Pailolo Channel, fine gray sand bottom, July 21, 1902; one specimen.

Distribution.—Hawaiian Islands (*Albatross*).

Material examined.—The unique type is the only specimen known.

Remarks.—Although in a rather badly macerated condition, as though taken from the stomach of some larger animal, the single specimen seen still retains enough of its original appearance to show features which forbid its reference to any of the previously described species of either *Abralia* or *Abraliopsis*. The lack of terminal organs on the ventral arms and the pale red-dotted buccal membrane alone serve to establish its identity as an *Abralia*, while the large fins indicate that it will prove to belong to the typical section of that genus. The species to which *A. trigonura* most closely approximates seems to be the *A. andamanica* Goodrich from the Bay of Bengal. The mantle of the Hawaiian species, however, appears to be relatively shorter and much more rapidly tapering, and such of the photogenic organs as can be made out fail to coincide in their arrangement with the description given by Goodrich, who fails to mention the definite series of these organs which here adorn the ventral aspect in so conspicuous a fashion that they can scarcely have been overlooked.

From the other known Hawaiian species, *A. astrodicta*, it is widely different. The short conical body, larger fins, more numerous small luminous organs on the ventral surface, and much smaller subocular organs are sufficient to distinguish it at a glance. As the specimens obtained of the two species are not very far from one another in size, it is evident that one can not be regarded as but a younger stage of the other.

Genus ABRALIOPSIS Joubin 1896.

Abraliopsis Joubin 1896, p. 19.

Abraliopsis Pfeffer 1900, p. 166, 168.

Abralia Pfeffer 1908a, p. 289-292.

Abraliopsis Chun 1910, p. 57, 78.

Abralia Pfeffer 1912, p. 124, 137.

Abraliopsis Pfeffer 1912, p. 764.

juv. = *Compsoteuthis* + *Micrabralia* Pfeffer 1900, p. 165, 167.

juv. = *Nepioleuthion* + *Prodromoteuthis* Pfeffer 1912, p. 149, 151, 165, 167.

Fins large, sagittate; acutely pointed posteriorly, and not exceeded by the tip of the equally pointed body. Arms with two rows of hooks throughout the greater part of their length, but with true suckers

at the tips of all the arms, as in *Abralia*, except the ventral pair which bear only hooks; extremities of ventral arms with a conspicuous series of heavily pigmented black bead-like organs probably photogenic in function. Left ventral arm hectocotylized, but distinguished chiefly by its very wide web with broad lappets at the margin; no glandular swellings. Two rows of suckers on proximal portion of tentacle club suppressed in adult, leaving either two rows of hooks or one row of hooks and one row of suckers, which give way distally to four rows of suckers. Buccal membrane deep violet in color. Photogenic organs of the mantle usually showing a definite bilateral arrangement; three rows of these organs present on the lower aspects of the ventral arms, two occurring on the arm itself, the other upon its marginal web. A single series of five large photophores occurs upon the ventral periphery of the eyeball, the terminal organs of this series being somewhat larger than the remainder.

Type.—*Enoploteuthis Hoylei* Pfeffer 1884 (designation); described from the Mascarene Islands.

Abraliopsis species (young).

Abraliopsis species Berry 1909, p. 419 (mere locality record).

Animal small. Mantle short, acutely conical, widely flaring in front. Fins relatively enormous, over two-thirds the length of the mantle and notably wider when taken together than the latter is long, anterior lobes prominent and angular.

Head small; only broader than long because of the large conspicuous eyes. Funnel flattened, little projecting.

Arms rather long, very slender and attenuate; decidedly unequal, their formula 4, 2, 3, 1; the ventral arms conspicuously longer than the others, the dorsal pair notably the shortest. Armature consisting of two alternating series of small elevated hooks, the latter persistent nearly to the tips of the arms, so that the usual suckers at the extremities are very small and obscure and have not in the present case been actually observed by me.

Buccal membrane eight-pointed; its coloration violet throughout except for the paler and more whitish trabeculae.

Photogenic organs of mantle conspicuous and exhibiting a very definite grouping, not even the smaller ones being very irregularly scattered; on the ventral surface of the mantle occur six very definite rather distant converging series, with traces of another row as represented by three or four widely spaced organs lateral to these. On the head three conspicuous rows (the only ones shown in the figure) with another weaker row lateral to these and a rather weak circle around the eyelid opening, making seven rows in all. Along the ventral aspect of the ventral arms there are two rows and one row on the third pair.

The ventral arms bear at their extremities a bead-like series of three distinctly separate smooth black ovoid swellings, the median one notably the largest.

The subocular organs are yellowish in color but too badly damaged to be made out very clearly.

Color in alcohol a brownish buff; the chromatophores darker but comparatively few in number. Photophores bluish with paler centers.

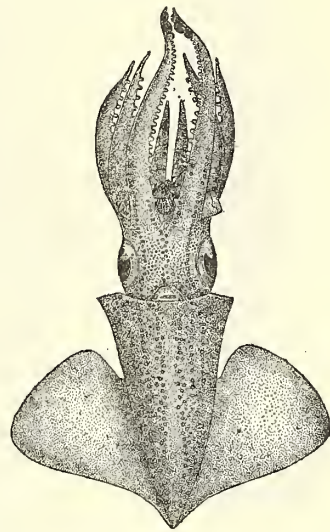


FIG. 34.—*Abraliopsis* sp., young, ventral view [276], $\times 2$. Drawn by R. L. Hudson. The representation of the photogenic organs is incomplete.

MEASUREMENTS OF ABRALIOPSIS SPECIES (YOUNG).

	mm.		mm.
Total length exclusive of tentacles.....	35	Length of—	
Length of mantle, dorsal.....	16	Head.....	5
Extreme length of fins.....	11	Dorsal arm.....	7
Length of fins at base.....	9	Second arm.....	12
Width across fins.....	19	Third arm.....	11
Width of mantle near anterior margin.....	7	Ventral arm.....	15
Width of head.....	6	Funnel.....	5

Material examined.—The single specimen was taken from the surface at Albatross station 3926, latitude $21^{\circ} 13' N.$, longitude $158^{\circ} 41' W.$, between Honolulu and Laysan Island [S. S. B. 276].

Remarks.—This specimen is clearly immature and withal very poorly preserved. The tentacles are missing and the integument disfigured with a whitish deposit, badly obliterating some of the important features. It is undoubtedly a young *Abrialiopsis*, however, and is very close to the stage described by Pfeffer as *Microbralia*.

Subfamily PYROTEUTHINÆ Pfeffer 1912.

Pterygiomorphæ Chun 1908, p. 86.

Pterygiomorphæ Chun 1910, p. 58, 108.

Pyroteuthinæ Pfeffer 1912, p. 124, 189, 773.

Body sharply pointed posteriorly, notably exceeding the large round separate fins. Buccal membrane joined with the basal web of the arms; dorsal lappets close together and coherent at base. Photogenic organs lacking from the outer integument, but numerous and polymorphic on the eyeball as well as within the pallial chamber.

Genus PTERYGIOTEUTHIS H. Fischer 1895.

Pterygioteuthis H. Fischer 1895, p. 205.

Pterygioteuthis Pfeffer 1900, p. 165, 166.

Pterygioteuthis Hoyle 1904, p. 39.

Pterygioteuthis Chun 1910, p. 58, 108.

Pyroteuthis (*Pterygioteuthis*) Pfeffer 1912, p. 193, 204, 774.

Ventral arms naked or with suckers only; remaining arms with a few of the middle suckers transformed to hooks. Tentacle club with four rows of suckers and no hooks; fixing apparatus composed of a very few suckers and pads. Left ventral arm hectocotylized, and furnished with a conspicuous glandular fold or swelling.

Type.—*Pterygioteuthis giardi* Fischer 1895 (monotypic); described from off the coast of Morocco.

Pfeffer has placed this genus under *Pyroteuthis* Hoyle 1904 as a subgroup; but even should this arrangement be accepted as zoologically correct, the name *Pterygioteuthis* has nine years' priority and should therefore be given precedence.

Pterygioteuthis microlampas Berry 1913. (Pl. LI, fig. 1-3.)

Pterygioteuthis giardi Berry 1909, p. 479 (locality record only).

Pterygioteuthis microlampas Berry 1913, p. 566.

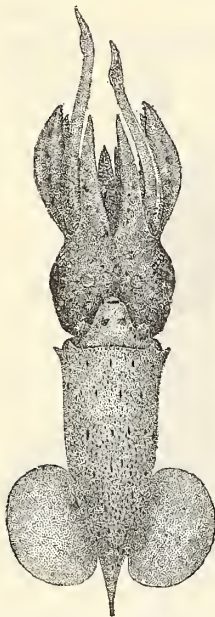


FIG. 35.—*Pterygioteuthis microlampas*, ventral view of female [278], $\times 2$. Drawn by R. L. Hudson.

Animal small, fragile, with a cylindro-conical body terminating posteriorly in a sharp spinelike process, which extends between the fins and well past them; mantle about one-third as wide as long. Fins rather large, prominent, longer than broad, circular, not adnate, attached along their inner margins for less than half their total length; anterior and posterior lobes about equal.

Head large, rounded, but little narrower than the mantle. Eyes large, prominent. Funnel large, broadly conical in outline; aperture small.

Arms short, nearly of a length, their order of relative length 3, 2=4, 1; outwardly keeled by a very fragile trabeculated membrane (most conspicuous on the arms of the third pair). Dorsal arms bare for the basal one-fourth of their length; at this point occur two very minute somewhat distant suckers, succeeded distally by six pairs of much larger suckers alternating in two series; the ventral members of the succeeding three pairs are transformed into hooks, after which the remaining suckers (about eight in number) steadily diminish in size to the extremity of the arm, there being 14 pairs of suckers or their homologues on the entire arm; distally a wide delicate trabeculated membrane (mostly torn away) occupies the ventral margin of the sucker-bearing area; the larger suckers have about four large long bluntly squarish teeth along the upper border of their horny rings. Arms of second and third pairs essentially similar in all respects to the dorsal arms, although larger and stouter. Ventral arms squarish,

much more slender, more acutely tapering; hooks entirely lacking; suckers exceedingly minute, occurring in two distant narrowly spaced rows of 10 to 14 suckers each, which are confined to the more distal portion of the arm.

Tentacles short, stout, cylindrical, but little longer than the arms; near the base of the stalk a conspicuous circular constriction, beyond which the stalk swells out again, attaining a diameter even greater than that of the proximal portion, thence tapering gradually to the short blunt unexpanded club. Suckers on inner surface of club minute, in four rows; the five proximal members of the dorsal row distinctly the largest, even exceeding in size the two suckers on the carpus, which together with two small pads constitute the fixing apparatus. (Pl. LI, fig. 3.)

Subocular photophores numerous, at least 14 on each eyeball, but in the present material exceedingly difficult to locate with certainty, due to the ease with which they become detached upon the removal of the outer lid. Most conspicuous are two very large circular organs situated one just behind the other on the ventral periphery of the eyeball, just in front of the funnel (fig. 36, no. 8 and 9). Well anterior to these and more or less in line with them are four very much smaller organs (nos. 11-14). Just posterior to the lens is a large conical organ (no. 10), while a conspicuous series of seven moderately large organs form an oblique curve in front (nos. 1-7). Of the latter the three upper (nos. 1-3) are very large and conical in outline: the next two and the last one are smaller, but the next to the last one (no. 6) is large flattened, of ovate outline, and pale in color, very different in appearance from any of the other organs. (See also pl. LI, fig. 1.)

Color in alcohol a grayish buff, the chromatophores somewhat darker. Buccal membrane purplish, with paler trabeculae. The gladius shows through the dorsal integument as a prominent median line.

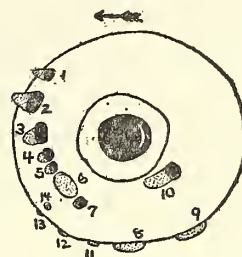


FIG. 36.—*Pterygioteuthis microlampas*, diagram to show arrangement of photogenic organs of left eyeball [277], $\times 5$.

MEASUREMENTS OF PTERYGIOTEUTHIS MICROLAMPAS.

Number in author's register.....	277	278	Number in author's register.....	277	278
Sex.....	♀	♀	Sex	♀	♀
Total length.....	mm. 31	mm.	Length of—	mm.	mm.
Tip of body to tip of arms.....	28	.....	Head.....	4	.....
Length of mantle, dorsal.....	18	.....	Dorsal arm.....	6.5	7
Width of mantle.....	6	6	Second arm.....	7.5	8
Extreme length of fins.....	8	.....	Third arm.....	8	8
Length of fins at base.....	3.5	.....	Ventral arm.....	7.5	7.5
Width across fins.....	14	.....	Tentacle.....	12	.....
Width across eyes.....	5.5	7			

Type.—Catalogue No. 214386, United States National Museum [S. S. B. 277].

Type locality.—Albatross station 4105, in 314 to 335 fathoms, Kaiwi Channel, bottom of fine coral sand and foraminifera, July 24, 1902; one ♀ specimen.

Distribution.—Hawaiian Islands (*Albatross*).

SPECIMENS OF PTERYGIOTEUTHIS MICROLAMPAS EXAMINED.

No. of specimens.	Locality.	Depth in fathoms.	Collector.	Sex.	Where deposited.	Author's register.
a 1	Kaiwi Channel.....	314-335	Albatross Sta. 4105.....	♀	U. S. Nat. Mus. Cat. 214386..	277
1	No locality.....	(?)	Albatross Sta. (?).....	♀	Fragmentary.....	278

Remarks.—Only two species of *Pterygioteuthis* have been recognized previous to the present one. The first of these and type of the genus is the *P. giardi* Fischer, originally described from a specimen taken by the *Talisman* at a depth of 1105 meters off the coast of Morocco. In 1904 Hoyle published a much more detailed account of some specimens thought to represent the same species which were captured by the *Albatross* in the eastern tropical Pacific at depths ranging from 551 to 1,201 fathoms. In 1908 Chun issued a brief diagnosis of a second species, *P. gemmata*, which was secured by the *Valdivia* expedition in the South Atlantic. When the present specimens from the *Albatross* Hawaiian collections were first being examined by the writer, Chun's paper had not yet come to hand, so that they were, after a little hesitation, referred to *P. giardi* and were indeed recorded under this name in a preliminary publication. Since that time the appearance of the great monograph of the *Valdivia* Oegopsids by Chun has greatly increased and simplified our understanding of the genus, so that upon a reexamination of the specimens and a patient working out of the details (often seriously obscured by the woeful preservation of the material) the conclusion was reached that a new species is represented, which though in many respects very close to *P. giardi*, in some ways shows an approach to *P. gemmata*, and in others is somewhat different from either. The relationship of the three species is well shown by a consideration of their more important diagnostic characters grouped in parallel columns.

DIAGNOSTIC CHARACTERS OF THE SPECIES OF PTERYGIOTEUTHIS.

<i>P. giardi.</i>	<i>P. microlampas.</i>	<i>P. gemmata.</i>
15 subocular organs; the 5 small anterior ones nearly in line with one another.....	14 subocular organs; arrangement similar to <i>P. giardi</i> , but 4 instead of 5 small anterior organs, and the last of these not in line with the others.	14 subocular organs; arrangement very different.
Dorsal arms with 3 hooks near middle of arm (both rows affected) and about 5 pairs of suckers proximally; 2d and 3d arms with 2-3 hooks (both rows). No suckers at tips of any arms save dorsal pair.	Dorsal arms with 3 hooks near middle of ventral row, with 6-7 pairs of suckers proximally; 2d and 3d arms with 3 hooks in ventral row and 7 suckers proximally; suckers continuing distally to tips.	Dorsal, 2d, and 3d arms with 4-5 hooks near middle of ventral row.
Ventral arms devoid of both hooks and suckers.	Ventral arms with no hooks; suckers minute and confined to distal half of arm.	Ventral arms with no hooks; but with small suckers throughout their length.
Two suckers in fixing apparatus.....	Two suckers in fixing apparatus.....	Three suckers in fixing apparatus.
Chitinous plate between the glandular ridges of the hectocotylus bidentate.	Hectocotylus unknown.....	Chitinous plate between the glandular ridges of the hectocotylus finely toothed.

It is an unfortunate but curious fact that practically all of the specimens of this genus which have been obtained have been defective in one way or another. As a rule either the eyes have burst or the arms are badly damaged or both types of mutilation have occurred. This appears to be due to the fragile and incoherent nature of the tissues, which seem unable to withstand the great changes in pressure which they are forced to undergo in being pulled up from the depths in which they live. According to present evidence it appears that even in a preserving medium they are apt to gradually disintegrate, and despite the utmost vigilance and care the handling necessarily incidental to a thorough examination is often fatal. This was the case with the specimen which was the subject of Mr. Hudson's excellent drawing, for though evidently perfect at that time, it was in such fragmentary condition when it came into my hands that no accurate description of it could be given and it became necessary to utilize the second individual as the type, although the account of the photogenic organs of the eye has been mainly drawn from the former specimen.

I can not forbear adding that there are certain discrepancies in the various descriptions given by Fischer, Joubin, Hoyle, and Chun for *P. giardi* which cause me to feel some doubt as to whether all their specimens are really referable to the same species, an uncertainty which is by no means diminished when the localities furnishing the respective specimens are taken into consideration.

Family HISTIOTEUTHIDÆ Verrill 1881.

- Histioteuthidæ* Verrill 1881, p. 431.
Histioteuthidæ Pfeffer 1900, p. 152, 168.
Histioteuthidæ Pfeffer 1908, p. 75.
Histioteuthidæ Chun 1910, p. 147.
Histioteuthidæ Pfeffer 1912, p. 243.

Body short, barrel-shaped; mantle thickened and fleshy. Fins relatively small, subterminal. None of the suckers on either arms or tentacles modified into hooks; two rows of suckers on sessile arms; on tentacle club more than four rows. Fixing apparatus a series of small suckers and pads extending across the carpal region of the tentacle and well down its stalk. Funnel locking cartilages simple linear grooves and ridges. Gladius simple, loliginiform, with broad wings. Photogenic organs of very characteristic structure plentifully developed over almost the entire outer surface of the mantle, head, and arms.

Histioteuthid species (young).

Ommastrephid (young) Berry 1909 (pars), p. 419 (mere locality record).

Body small, ovate, considerably over half as broad as long. Fins very small, subterminal, and decidedly dorsal in position, with a nearly circular outline; practically continuous posteriorly. Anterior margin of mantle obtusely angled in the median line above; slightly emarginate below the funnel.

Head about half as large as the body; flattened above and below. Eyes rounded, prominent; their apertures small, angled in front but otherwise entire. Funnel rather large, little projecting. Mantle connects a pair of simple grooves with thickened and reflexed margins at the base of the funnel articulating with narrow linear ridges on the inner surface of the mantle.

Arms over half as long as the mantle; rather stout; unequal, the order of length 2, 3, 1, 4. Suckers minute, spherical, biserial; horny rings well developed.

Tentacles but little longer than the arms. Club slightly expanded and armed with four rows of minute crowded suckers, the two outermost of which continue down the stalk nearly to its base.

Color in alcohol a dull brownish buff. The chromatophores are large, slate colored, thickly distributed above, but not without certain hints of a symmetrical arrangement in seven to eight more or less obscure transverse rows; much paler and less crowded below. Pigmentation on dorsal surface of head extremely dense. A single series of large chromatophores extends along the outer surfaces of all the arms, dark in color on the dorsal pair, but so pale as to be scarcely visible below. There are two distinct chromatophores placed opposite one another on the ventral aspect of the funnel not far from the middle.

Total length of largest specimen, 11 mm.; of mantle, 5 mm.; of head, 2.5 mm.; of arm of second pair, 3 mm.; of tentacle, 3.5 mm.; width of mantle, 3 mm. Length of smallest specimen, 9 mm. of mantle, 4 mm.

Three specimens of this curious larval form were taken by the *Albatross* in the surface net at station 4190, latitude 34° 39' 18" N., longitude 132° 04' W. [S. S. B. 254].

Although minute and offering no very conspicuous characters of their own, the above specimens undoubtedly represent larval stages of some *Histioteuthid*, perhaps *Calliteuthis* or some nearly related form. Although in all essential features they resemble the young *Histioteuthid* described by Pfeffer in Hoyle 1907, p. 1-2, sufficient minor differences are evident to render it probable that they belong to another species, even if referable to the same genus. From the young *Ommastrephids* with which they were at first confounded, the strong pigmentation, larger head, and longer arms are sufficient for their ready separation.

Family BRACHIOTEUTHIDÆ Pfeffer 1908.

Tracheloteuthidæ Pfeffer 1900, p. 152, 174.

Brachioteuthidæ Pfeffer 1908, p. 62, 78.

Tracheloteuthidæ Chun 1910, p. 205.

Brachioteuthidæ Pfeffer 1912, p. 345.

Body slender, loliginiform. Fins large, rhombic. None of the suckers on either arms or tentacles transformed to hooks; arms with two rows of suckers; tentacles with four or more rows. No fixing apparatus. Funnel locking cartilages simple and linear. Gladius slender, consisting for the most part of little but the rhachis; terminating in a long pointed cone.

Genus BRACHIOTEUTHIS Verrill 1881.

Brachioteuthis Verrill 1881, p. 405.

Brachioteuthis Pfeffer 1900, p. 174, 176.

Brachioteuthis Chun 1910, p. 206.

Brachioteuthis Pfeffer 1912, p. 346.

Characters of genus identical with those of the family, for the latter becomes monogeneric upon the union of *Tracheloteuthis* with *Brachioteuthis*, as is now very generally advocated.

Type.—*Brachioteuthis Beanii* Verrill 1881 (designation); a species of the New England region.

Subgenus TRACHELOTEUTHIS Steenstrup 1882.

Tracheloteuthis Steenstrup 1882, p. 294.

Verrilliola Pfeffer 1884, p. 22.

Entomopsis de Rochebrune 1884, p. 15.

Tracheloteuthis Hoyle 1886, p. 163.

Tracheloteuthis Pfeffer 1900, p. 174, 175.

Tracheloteuthis Pfeffer 1908, p. 78.

Brachioteuthis (pars) Chun 1910, p. 206.

Brachioteuthis (*Tracheloteuthis*) Pfeffer 1912, p. 355.

Mantle very thin, membranous. Entire animal nearly colorless except for a few chromatophores on the head and a very few scattered ones on the body. Fins large, rhombic, but never as long as half the mantle length.

Type.—*Tracheloteuthis Riisei* Steenstrup 1882 (species first mentioned); a species of almost cosmopolitan distribution.

***Brachioteuthis* (*Tracheloteuthis*) *riisei* (Steenstrup 1882).**

Tracheloteuthis Riisei Steenstrup 1882 p. 294.

Tracheloteuthis Behnii Steenstrup 1882, p. 294.

Tracheloteuthis riisei Hoyle 1886, p. 36, 164, 213, 221, pl. 28, fig. 6-12.

Tracheloteuthis Behnii Weiss 1888, p. 85, pl. 10, fig. 1-4.

Tracheloteuthis riisei Lönnerberg 1897, p. 603 (account of funnel organ).

Tracheloteuthis riisei Pfeffer 1900, p. 175.

Tracheloteuthis Riisei Hoyle 1905a, p. 93, pl. 14, fig. 1-5.

Tracheloteuthis riisei Pfeffer 1908, p. 79, fig. 93-95.

Tracheloteuthis Riisei Massy 1909, p. 30.

Tracheloteuthis riisei Berry 1909, p. 419 (mere locality record).

Brachioteuthis Riisei Chun 1910, p. 207.

Brachioteuthis (*Tracheloteuthis*) *Riisei* Pfeffer 1912, p. 355, pl. 26, fig. 1-20; pl. 27, fig. 1-9.

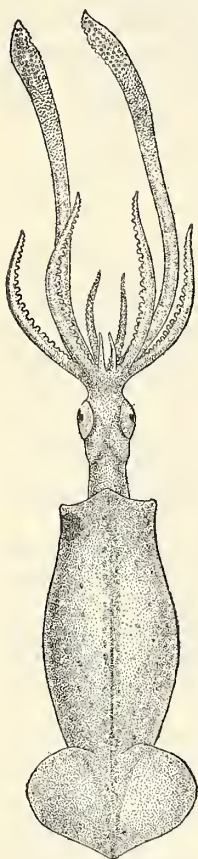


FIG. 37.—*Brachioteuthis* (*Tracheloteuthis*) *riisei*, dorsal view of specimen [280], from station 3878, X 2. Drawn by R. L. Hudson.

Animal small, pelagic, hyaline, extremely slender and graceful. Mantle very thin, inflated, elongate-cylindrical; swollen at the middle and tapering to an acute slightly attenuate point posteriorly; pallial chamber capacious, very scantily occupied by the delicate viscera. Mantle opening very wide, due largely to the extreme length and narrowness of the neck; anterior margin sharply angled in the medio-dorsal line, the ventro-lateral projections also well marked but somewhat less pronounced.

Fins fairly large, a little over one-fourth as long as the mantle; each one taken singly, a little longer than broad; barely separated in the medio-dorsal line by the narrow membrane covering the slender gladius, which extends past them as an acute point.

Head small, flattened, elongate, distinctly wider than the stalklike neck. Eyes large, little projecting; their apertures ample, with a slight obtuse anterior sinus. Funnel large, thin-walled, only its tip protruding beyond the mantle margin; valve minute. Funicular locking cartilages simple, with nearly straight grooves.

Arms conspicuously unequal, their order of length 2, 3, 4, 1; the lateral arms not only immensely longer than those of the dorsal and ventral pairs, but also more robust in every way; dorsal arms exceedingly short and weak, slightly recurved; the length of the second arms is about 5 to 6 times that of the dorsals, the third arms about $4\frac{1}{2}$ times, and the ventrals $2\frac{1}{2}$ to $3\frac{1}{2}$ times; lateral arms usually a little more than half as long as the body, exceedingly slender and graceful, with a delicate narrow membrane or keel along their outward aspect. Suckers small, not crowded; pedicels conical; horny rings toothed.

Tentacles more robust, thicker, and much longer than any of the arms, attaining approximately twice the length of the second pair. Club little expanded; distal portion tapering and with a conspicuous dorsal keel; at this region the inner face of the club bears four rows of minute suckers (horny rings toothed), which increase regularly in size from the dorsal to the ventral row, the latter suckers long pediceled and with a diameter about three times that of the dorsal ones; distally all the acetabula regularly diminish in proportion, but proximally to this region those of the dorsal row about maintain their size, the remaining rows diminishing in size but greatly increasing in number so that we henceforth find at least eight closely crowded series of minute subequal suckers extending for perhaps a third the length of the tentacle, after which they again thin out; two of the rows continue down the stalk in distantly placed alternating series for another third of its length.

Gladius long, slender, consisting chiefly of the rhachis, and terminating in a delicate hollow cone; midrib visible through the dorsal integument as a narrow horn-colored line.

Color in alcohol everywhere a very pale brownish buff, the head and eyes darker; head brown, eyes with a slaty tone. Chromatophores sparse, pale, indistinct; a longitudinally-arranged series extends along the dorsal aspect of the mantle on either side of the gladius.

MEASUREMENTS OF TRACHELOTEUTHIS RIISEI.

Number in author's register.....	280	280	280	280	280	280	280
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Total length.....	60	59	58	58	55	55	45
Length, excluding tentacles.....	46	45	46	45	41	41	33
Tip of body to base of dorsal arms.....	32	31	32	31	31	30	26
Length of mantle, dorsal.....	25	24	25	23	23	23	17
Extreme length of fins.....	6.5	6.5	7	6	6	5.5	3
Width across fins.....	10	10	11	10	9.5	8.5	7
Width of mantle.....	7.5	6	7.5	7	7	7	6
Width of head.....	2.5	2.5	3	2.5	2.5	2.5	2
Length of—							
Head.....	4	3.5	4.5	3.5	3.5	4	3
Dorsal arm.....	3	2.5	2.5	2.5	2	2	1.5
Second arm.....	15	14	14	13	12	11	7
Third arm.....	11	11	12	11	9	9.5	6
Ventral arm.....	7	7	7	8	7	5	3
Tentacle.....	27	25	28	27	24	24	21

Type.—In the Copenhagen Museum.

Type locality.—Latitude $34^{\circ} 40'$ S., longitude 7° W. (*vide* Hoyle).

Distribution.—North Atlantic (Lönnberg); off coast of Ireland (Hoyle, Massy); Faeroe Channel (Fowler); Messina, Sicily (Weiss, Hoyle); Gulf of Naples (Jatta); coast of Morocco (Joubin); St. Paul Island (de Rochebrune); Zanzibar (Pfeffer); Indian Ocean (Hoyle); west coast of New Guinea (Hoyle); Solomon Islands (Pfeffer); Hawaiian Islands (*Albatross*); between Honolulu and San Francisco, California (*Albatross*); Chile (Pfeffer).

SPECIMENS OF TRACHELOTEUTHIS RUSEI EXAMINED.

No. of specimens.	Locality.	Depth.	Collector.	Author's register.
7	South of Lanai	Surface....	Albatross station 3878	280
1	34° 39' 18" N. lat., 132° 04' W. long.....	...do.....	Albatross station 4190	281

Remarks.—These specimens, all of which are of approximately the same size and developmental stage as the one selected for figuring, are of interest here chiefly because they serve to extend the known range of this curious pelagic species over a much greater area of ocean it was previously reported to inhabit. There is small doubt that it will eventually prove to have an almost universal dispersion in the warmer currents of the ocean.

Family OMMASTREPHIDÆ Gill 1871.

Ommastrephini Steenstrup 1861, (*vide* Hoyle).

Ommastrephidæ Gill 1871, p. 1.

Ommastrephidæ Verrill 1881, p. 428.

Ommastrephini Hoyle 1886, p. 32, 162.

Ommastrephidæ Pfeffer 1900, p. 153, 176.

Ommastrephidæ Pfeffer 1908, p. 62, 87.

Ommastrephidæ Pfeffer 1912, p. 369.

Animal usually of moderate size, but often of considerable dimensions; loliginiform. Fins large, sagittate, subterminal. Suckers in two rows on the arms, usually four rows on the clubs of the tentacles; none of the suckers modified into hooks. Fixing apparatus a single series of modified suckers and pads at the base of the club. Funicular cartilages highly developed, complex; their major outlines 1-shaped. Gladius consisting of little but the rhachis throughout the greater portion of its length; terminating posteriorly in a deep hollow cone. The occurrence of photogenic organs has not been described in any of the genera except *Hyaloteuthis*.

Genus OMMASTREPHEs d'Orbigny 1835.

*Ommastrephe*s d'Orbigny 1835, p. 45.

*Ommastrephe*s d'Orbigny 1845, p. 412.

*Ommastrephe*s Lovén 1846 (*vide* Hoyle).

*Ommastrephe*s (pars) Verrill 1880a-1881, p. 267, 385.

Todarodes Steenstrup 1880, p. 83 (13).

*Ommastrephe*s Pfeffer 1900, p. 178, 179.

*Ommastrephe*s Hoyle 1902, p. 198.

*Ommastrephe*s Pfeffer 1908, p. 89, 92.

*Ommastrephe*s Pfeffer 1912, p. 388, 438.

Funnel groove with a foveola. Horny rings of large tentacular suckers with the teeth either nearly subequal, or with one or more of the apical denticles somewhat enlarged. Fixing apparatus very poorly developed. Sucker bearing portion of tentacle extending for more than half the total length.

Type.—*Loligo sagittata* Lamarck 1799 (species first mentioned); a common Atlantic species.

Ommastrephes hawaiiensis Berry 1912. (Pl. LIV, fig. 2.)

?*Ommastrephes sloanei* Schauinsland 1899, p. 92 (listed from Laysan Island).

Ommastrephes sagittata near *sloanei* Berry 1909, p. 418 (mere locality records).

?*Ommastrephe*s *Sloanei* *Sloanei* (pars) Pfeffer 1912, p. 458.

Ommastrephes hawaiiensis Berry 1912b, p. 434, 437.

Animal loliginiform, moderate in size. Mantle cylindro-conical, widest somewhat in advance of the middle, thence tapering very rapidly to an acute point between the fins; margin smooth and entire above, slightly emarginate below the funnel. Fins only moderately large, triangular when taken

singly, together broadly sagittate; posterior outlines nearly straight, anterior ones arcuate and lobed at the inner margin; total length a little less than two-fifths that of the mantle.

Head large, a little broader than the body; flattened above and below; bounded posteriorly by raised thickened fleshy ridge, which is continuous with the three ear-like folds behind the eye composing the so-called olfactory crest. Eyes large, the large lid apertures with a small indented sinus in front.

Arms moderate, stout, squarish, little attenuate, their average length about half that of the mantle; order of length in general 2, 3, 1, 4, or in younger specimens 2, 3, 1=4; not webbed at the base, but all strongly keeled along the outer angle, and with a narrow trabeculated membrane bordering the margins of the sucker-bearing area; the latter attaining its maximum along the ventral margins of the third arms, but scarcely developed on the ventral pair. Suckers large, distant; regularly alternating in two series so closely appressed together that they have rather the appearance of a single zigzag row; those of the dorsal arms distinctly smaller than the others; those of the lateral pairs largest, some of those near the middle of the arm attaining a diameter almost as great as that of the arm itself; on the arms of the second pair only about 36 to 40 suckers in all can be readily counted. Horny rings of the larger suckers with 19 to 21 teeth, the upper median tooth conspicuously the largest and more regularly conical in shape than the others; those of the lower margin blunt and much reduced (obsolete in the smaller suckers), the remainder acutely pointed; an occasional very minute denticle may be interpolated among the teeth of the upper margin.

Tentacles stout, of moderate length, some two-thirds or more as long as the mantle; outer margin carinate; club slightly expanded, large, the sucker bearing area including 64 to 70 per cent of the total length of the tentacle. Suckers in four rows; all of small size at the extremity, the ventral row largest, thence very regularly decreasing in size dorsally; at the middle of the club the dorsal and ventral series about equal, but still very small and widely spaced, the suckers of the two median rows immensely larger (and therefore more crowded) and basin shaped, but proximally again showing a diminution in size; at the base of the club the central rows terminate, the marginal series continuing past them for a short distance down the stalk.

FIG. 38.—*Ommastrephes hawaiiensis*, ventral view of type [243]. $\times \frac{1}{2}$. Drawn by R. L. Hudson.

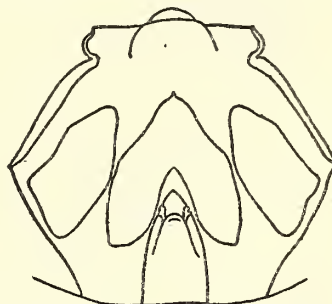
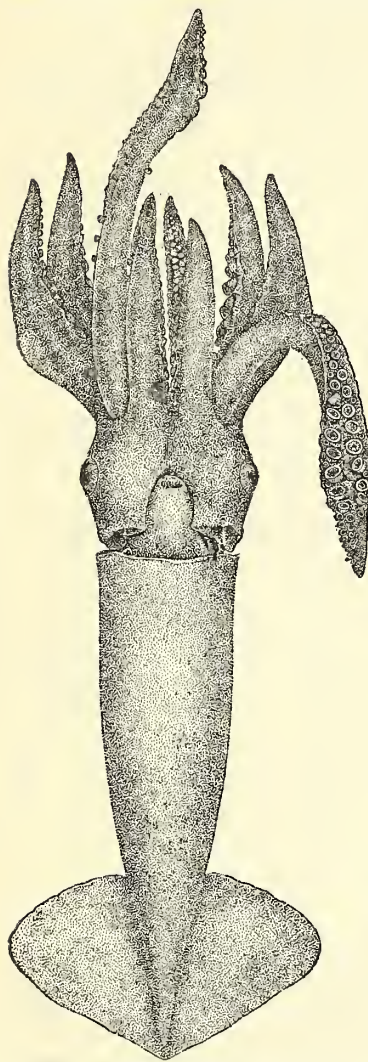


FIG. 39.—*Ommastrephes hawaiiensis* [243] outline drawing of funnel organ, natural size.

The horny rings of the large median suckers are toothed all round, the 13 to 16 acutely-pointed curved teeth occurring in regular alternation with an equal number of wide, low, very thin arcuate plates; upper median tooth much larger and more pointed than the others, very much as already noted in the case of the suckers of the sessile arms. The small marginal suckers are much

deeper above and bear about 20 teeth, which are very long, slender and acute on the upper margin (obtuse and reduced below) and occur in alternation with minute bluntish denticles; none of the teeth in these suckers notably larger than the others. I can not make out any pads or specially differentiated suckers which could be construed as constituting a fixing apparatus.

Color in alcohol the usual brownish buff dotted with brown chromatophores.

MEASUREMENTS OF OMMASTREPHES HAWAIIENSIS.

Number in author's register.....	242	243 (type)	244	245	248
	<i>mm.</i>	<i>mm.</i>	<i>mm.</i>	<i>mm.</i>	<i>mm.</i>
Total length.....	285	282	195	151	207
Tip of body to tip of arms.....	249	239	179	131	172
Length of mantle, dorsal.....	147	138	107	81	105
Width of mantle near middle.....	31	33	23	21	22
Width across fins.....	76	76	54	42	.....
Extreme length of fins.....	56	52	37	27	.....
Length of fins at base.....	50	45.5	33	22	.....
Length of head.....	35	28	22	18	18
Width of head.....	50	37	25	22	23
Length of—					
Right dorsal arm.....	60	62	41	26	35
Right second arm.....	76	77	50	33	42
Right third arm.....	78	76	48	32	50
Right ventral arm.....	58	60	41	26	41
Right tentacle.....	118	118	67	48	80
Sucker-bearing portion of right tentacle.....	81	80	43	32	43 [†]
Left tentacle.....		119	66	50	74
Sucker-bearing portion of left tentacle.....		81	44	35	43 [†]

Type.—Catalogue no. 214382, United States National Museum [S. S. B. 243].

Type locality.—Albatross station 4177, 253 to 282 fathoms, off Kahuku Point, northwest coast of Oahu, bottom of coral sand and foraminifera, July 25, 1902; one specimen.

Distribution.—Hawaiian and Midway Islands (*Albatross*).

SPECIMENS OF OMMASTREPHES HAWAIIENSIS EXAMINED.

No. of specimens.	Locality.	Depth in fathoms.	Collector.	Remarks.	Author's register.
1	Honolulu.....		Albatross expedition.....	Young; badly desiccated....	247
1	Honolulu market.....		do.....		383
1	Pailolo Channel.....	256-283	Albatross station 3865.....		242
1	Off Kahuku Point, Oahu.....	253-282	Albatross station 4117.....	Type; U. S. Nat. Mus., Cat. 214382.	243
1	Off Hanamaulu, Kauai.....	257-312	Albatross station 4132.....		244
1	Off Puniawa Point, Maui.....	220-238	Albatross station 4082.....		245
1	Laysan Island.....		Albatross hydrographic station 4353.	From stomach of <i>Sula piscator</i> .	248

Remarks.—This is one of the commonest Hawaiian squids and probably a species of considerable economic value in its food relations to many sea birds and the larger fishes. Because it is so abundant and characteristic a member of the fauna of this region, I have little doubt that the specimens listed by Schauinsland and more recently Pfeffer from Laysan Island as *O. sloanei* are the same form. The true *O. sloanei*, however, appears to be a somewhat different creature, as Gray expressly states that the horny rings of the suckers have the "higher side with *regular* acute teeth, lower *smooth*" (*italics mine*), while the remainder of Gray's diagnosis is so sadly incomplete or even silent regarding what should prove to be features of the highest importance, that there seems every likelihood that other even more striking differences will eventually appear. *O. hawaiiensis* is undeniably a near relative of the Japanese *O. pacificus* Steenstrup, considered by many to be a synonym of *O. sloanei* (cf. Berry 1912b, p. 436-437), but the specimens before me differ consistently in their more rapidly tapering body, slightly shorter fins, much larger and wider head, very much fewer and larger suckers on the sessile arms (especially

the second and third pairs), and the fact that the teeth of the latter are not subequal but the middle tooth on the upper side is conspicuously larger than its neighbors, showing in this last character an approach to the condition prevailing in the Atlantic *O. sagittatus*. From this résumé it would appear that *O. hawaiiensis* is in some respects intermediate between *O. sagittatus* and *O. pacificus*, while in a few particulars it is somewhat different from either.

The position of *O. sloanei* I am now disposed to regard as more doubtful than ever, for undoubtedly the union of *O. pacificus* with it was more premature than the meager evidence would justify. The habitats of all three of the Pacific forms are still widely separated, and further material, particularly from southern localities, is an important desideratum.

Genus SYMPLECTOTEUTHIS Pfeffer 1900.

Symplectoteuthis Pfeffer 1900, p. 178, 180.

Symplectoteuthis Pfeffer 1912, p. 388, 501.

Funnel groove with a foveola. Funicular locking cartilages fused with those of mantle on at least one side. Horny rings of large tentacular suckers with one tooth in each quadrant much enlarged. Sucker-bearing portion of tentacle comprising less than half the total length. Fixing apparatus composed of a few heavy pads and smooth-ringed suckers.

Type.—*Loligo oualaniensis* Lesson 1830 (monotypic); a species of the tropical Pacific.

Symplectoteuthis oualaniensis (Lesson 1830) Pfeffer 1900.

Loligo oualaniensis Lesson 1830, p. 240, pl. 1, fig. 2.

Ommastrephes oualaniensis d'Orbigny 1845, p. 427.

Ommastrephes oualaniensis Tryon 1879, p. 180, pl. 81, fig. 368 (after d'Orbigny).

Ommastrephes oualaniensis Schauinsland 1899, p. 92 (listed from Laysan).

Symplectoteuthis oualaniensis Pfeffer 1900, p. 180.

Symplectoteuthis oualaniensis Hoyle 1904, p. 32, fig. F.

Symplectoteuthis oualaniensis Berry 1909, p. 419 (merely listed).

Symplectoteuthis oualaniensis Pfeffer 1912, p. 502, pl. 40, 41; pl. 42, fig. 1-4.

I have seen no specimens of this species, but include it here on the authority of Schauinsland, who found it one of three species of squid which compose a chief food for the Laysan albatross. It is an abundant species of wide distribution, having been reported from the Red Sea, Laccadive Islands, Japan, Australia, the Cocos Islands, and Laysan. It may be readily recognized by the compressed arms, short tentacle club, and the fusion of the ventral mantle locking cartilages with those of the funnel.

Genus RHYNCOTEUTHION Pfeffer 1908.

Rhyncoteuthis Chun 1903, p. 716 (not of d'Orbigny 1847).

Rhyncoteuthis Hoyle 1904, p. 32.

Rhyncoteuthion Pfeffer 1908, p. 88.

Rhyncoteuthis Chun 1910, p. 201.

This is a name which has been applied to various larval *Ommastrephidæ* during the curious stage when the tentacles are fused along a portion of their inner faces, to form in some cases an elongate proboscis-like organ, or in others a pincer-shaped organ. The development and relationships of the different forms which have been described is still so insufficiently known that it is impossible to refer them to the proper adult form, so that it is convenient to give them provisional consideration by themselves.

Type.—No type has ever been given and but one species (*R. chuni* Hoyle 1904) has received a specific name.

Rhyncoteuthion α. (Pl. LIII, fig. 1.)

Cf. *Rhyncoteuthis chuni* Hoyle 1904, p. 32, fig. G.

Ommastrephid (young) Berry 1909 (pars), p. 419 (mere locality records).

Animal small, pelagic. Body rather short, robust, cylindrical, tapering to a blunt point posteriorly; width of mantle in largest specimens less than half its length, in smaller examples considerably more than half its length. Fins extremely short and broad in the larger specimens (mantle length of 20 mm.), more rounded and very minute in the smaller, with all variations between; subterminal to terminal. Locking cartilages typically *Ommastrephid*.

Head short, broad, flattened, averaging about the same width as the mantle. Eyes large and in all but the largest specimens prominently protruding; lid openings with a small sinus in front.

Arms very short and stout; second and third pairs longest, ventrals shortest, a condition especially apparent in the more minute specimens; lateral arms (especially the third pair) outwardly keeled, but true umbrella wanting. Suckers minute, spherical, in two series.

Tentacles but little longer than the arms, but their appearance very variable. In the smallest specimen seen (mantle length of 5 mm.) they are slender, fused along their inner faces for the greater portion of their length, but free at the extreme base and at the extremities, which bear a few suckers (3 to 4 each), one of the latter being so conspicuously larger than the remainder as to be barely visible to the unaided eye. In slightly larger specimens (mantle length of 6.5 to 7 mm.) the tentacles are more completely separated but are yet fused for a short distance near the base of the small recurved pointed club (this is the condition typical of Hoyle's *R. chuni*), and minute swellings, the rudiments of future suckers, are now visible on the club distal to the large sucker and group of smaller ones mentioned above. Soon after this (mantle length of 9 mm.) the tentacles become entirely free of one another, though still bent strongly inward and with the tips still recurved. Further development is now rapid and the largest specimens show four longitudinal series of extremely minute suckers, those of the two outer rows much smaller than the central ones and already extending down onto the short robust stalk. The four carpal suckers are still separately distinguishable, but are now no larger than the median ones farther distad.

Color in alcohol a pale brownish buff, the chromatophores brown. The latter show a very constant disposition, forming (1) a broad transverse girdle around the middle of the body, shading paler at its anterior and posterior margins, and (2) an irregular dotting over the dorsal surface of the head, with a tendency to concentrate into two dark roundish spots, one over either eye.

MEASUREMENTS OF RHYNCOEUTHION α .

Number in author's register...	255	255	253	Number in author's register...	255	255	253
	mm.	mm.	mm.		mm.	mm.	mm.
Total length.....	35	23	11	Length of—Continued.....			
Length of mantle, dorsal.....	21.5	15	6	Dorsal arms.....	7	5.5	2
Length of fins.....	4.5	3	1.5	Second arms.....	8+	6.5	2+
Width across fins.....	11.5	8.5	3	Third arms.....	8—	6	2—
Width of mantle.....	9	7.5	5	Ventral arms.....	6	4	1
Width of head.....	9.5	8	4	Tentacles.....	10	7	.....
Length of—				Sucker bearing portion of tentacles.....	6.5	5	.....
Head.....	5	4	2				

SPECIMENS OF RHYNCOEUTHION α EXAMINED.

No. of specimens.	Locality.	Depth.	Collector.	Remarks.	Author's register.
2	Off Mokapu Islet, Molokai.....	Surface....	Albatross station 3889.....	Tentacles of 1 fused; others free.	249
1	Off Diamond Head, Oahu.....	.....do....	Albatross station 3912.....	Tentacles free.....	250
5	Between Honolulu and Laysan.....	.....do....	Albatross station 3926.....	.....do.....	255
1	Between Oahu and Kauai.....	.....do....	Albatross station 3980.....	.....do.....	251
1	.....do.....	.....do....	Albatross station 4010.....	Tentacles fused.....	252
1	Off Modu Manu.....	.....do....	Albatross station 4152.....	.....do.....	253

Remarks.—This is a very interesting series and very beautifully shows the ontogenetic transition from the small larva with proboscoidiform tentacles similar to that originally figured by Chun to the normal juvenile stage with free tentacles. Originally fused throughout practically their entire length, these organs begin to separate at the base as growth ensues, and then gradually split apart, the carpal region of the clubs marking the point of most persistent adhesion. Microscopical preparations show that the integument is truly continuous at the area of junction and that therefore the union is not merely a mechanical one.

Individuals of the corresponding stage in the degree of separation of the tentacles approximate very closely to the brief account and figure of *R. chuni* as given by Hoyle, and may very well be congeneric with it, although only the identification of the adults will show whether they are referable to the same species. The fact that the suckers extend more than half way along the tentacles of the largest specimen affords a certain suggestion that the present series are larval *Ommastrephes hawaiiensis*.

Rhyncoteuthion β .

Animal small, pelagic; mantle elongate, less than half as wide as long; nearly cylindrical, slightly tapering, bluntly pointed posteriorly. Fins almost continuous above, minute, rounded, subterminal. Anterior margin of mantle with a faint medio-dorsal angle; very weakly emarginate below the funnel. Locking apparatus typically *Ommastrephid*.

Head small, flattened; a little wider than the body. Eyes large, rounded; apertures angled in front. Funnel short, broad, not reaching to the eye openings.

Arms very short, unequal, the ventral pair decidedly the shortest; suckers moderately large, biserial, obliquely placed on short pedicels; horny rings minutely toothed.

Tentacles shorter than the arms, and remarkable in that their inner faccs are fused with one another for only a short space below the free recurved tips. When examined with a high-power lens each tentacle is seen to be furnished with a number of small suckers just distal to the point of fusion, one of which is greatly larger than the others, hood shaped, distinctly pediceled, its horny ring minutely toothed, median in position, and placed in close opposition to its mate of the other tentacle.

Color in alcohol a pale brownish buff, the chromatophores considerably darker. There is a pair of large rather conspicuous chromatophores transversely placed on the dorsal aspect of the head.

MEASUREMENTS OF *RHYNCOTEUTHION* β .

	mm.		mm.
Total length.....	12.5	Width across fins.....	3
Length of mantle, dorsal.....	8	Length of fins.....	1.5
Width of mantle.....	3	Length of second arms.....	2.5
Width of head.....	3.5	Length of tentacles.....	1.5
Length of head.....	2		

Material examined.—The single specimen was taken from the surface *Albatross* station 3930, latitude $25^{\circ} 07' N.$, longitude $170^{\circ} 50' W.$, between Honolulu and Laysan Island (S. S. B. 246).

Remarks.—The unique specimen forming the subject of the foregoing account is a minute squid at once distinguishable from the preceding by its elongate more pointed body and entirely different arrangement of the chromatophores. The curious pair of large opposite suckers on the tentacles may merely represent the first of these structures to become fully differentiated, but their entire aspect is rather that of some temporary larval adaptation.

Family CHIROTEUTHIDÆ Gray 1849.

Chiroteuthidæ Gray 1849, p. 36, 42.

Chiroteuthidæ Verrill 1881, p. 430.

Chiroteuthidæ Pfeffer 1900, p. 153, 183.

Chiroteuthidæ Chun 1910, p. 216.

Chiroteuthidæ Pfeffer 1912, 539.

Body soft and semigelatinous or somewhat membranous. Mantle elongate, terminating in an acute and often slender point. Fins large. Head elongate; "olfactory tubercle" stalked. Arms with two rows of suckers, the ventral pair usually conspicuously the longest and largest. Tentacles very long, the stalk without suckers; club with four or more rows of suckers; none of the suckers on either arms or tentacles modified into hooks. Funicular locking cartilages broad, deeply grooved, usually more or less ear-shaped. Gladius slender, with weak narrow wings and a long cone. Photogenic organs may occur over the outer surface of the body, on the eyeball, or within the pallial chamber; frequently absent.

Subfamily MASTIGOTEUTHINÆ (Verrill 1881) Chun 1908.

Mastigoteuthida Verrill 1881a, p. 100.*Mastigoteuthina* Chun 1908, p. 87.*Mastigoteuthina* Chun 1910, p. 219, 220.*Mastigoteuthina* Pfeffer 1912, p. 540, 608.

Olfactory tubercle or papilla short-stalked. Tentacles long and slender; club not expanded and without glandular swellings at tip. Photogenic organs in some cases numerous developed over the entire integument, sometimes lacking; no photophores upon the eyeball or within the pallial chamber.

Genus MASTIGOTEUTHIS Verrill 1881.

Mastigoteuthis Verrill 1881a, p. 100.*Mastigoteuthis* Pfeffer 1900, p. 184, 187.*Mastigoteuthis* Chun 1910, p. 220.*Mastigoteuthis* Pfeffer 1912, p. 609.

The characters of this genus coincide with those of the subfamily of which it is the only known representative.

Type.—*Mastigoteuthis Agassizii* Verrill 1881 (monotypic); a North Atlantic species.

Mastigoteuthis (?) famelica (Berry 1909) Pfeffer 1912. (Pl. LII, fig. 6-8.)*Chiroteuthis famelica* Berry 1909, pp. 414, 419, fig. 8.*Mastigoteuthis (?) famelica* Pfeffer 1912, p. 624.

Animal small, graceful, its outlines attenuate. Mantle cylindrical, extremely long and narrow; gradually tapering for a little more than half its length, then becoming suddenly constricted to continue as an exceedingly slender and delicate spit extending between the fins and somewhat exceeding them posteriorly; anterior margin sinuous, inflated, projecting in an obtuse point in the medio-dorsal line. Fins enormous, leaflike, not lobed; at the base relatively thick and fleshy, but thin at the margins; each one about three times as long as wide and extending for a little more than half the length of the mantle; separated only by that portion of the slender posterior extension of the mantle which covers the delicate gladius; in front the attached margins extend well forward on the dorso-lateral surfaces of the main body.

Head small, narrower than the body except across the eyes, whence it rapidly tapers to the narrow elongate neck (the neck is rather longer than wide); dorsal and ventral surfaces flattened. Eyes large, rounded, conspicuous, somewhat protruding; very anterior in position. "Olfactory papilla" short, but possibly not well represented in the present specimen. Funnel small, broadly conical, not quite reaching to the eyes. Funicular locking cartilages deep, ear-shaped, with ridges to correspond on the inner surface of the mantle.

Arms, except the ventrals, extremely short in proportion to the length of the body; decidedly unequal, the order of relative length being 4, 2, 3, 1. Ventral arms enormously developed, about three times as long as the others and half as long as the body; squarish; sucker-bearing surface very narrow in proportion to the total diameter of the arm and furnished with two alternating rows of distant minute slender pedicled suckers, the horny rings of the latter minutely toothed. Remaining arms more nearly of a length, the dorsal pair a little the shortest and weakest; their suckers slightly larger and more crowded. All the arms obscurely keeled. Umbrella and lateral membranes wanting.

Tentacles missing.

Gladius extremely long and slender, the posterior cone terminating in a long needle-like point; visible through the dorsal integument as a dark medio-longitudinal line.

Color in alcohol a pale brownish buff; chromatophores brown but very sparsely distributed. Such portions of the outer integument as remain intact are devoid of photogenic organs, and I have not succeeded in identifying any of these structures upon the eyeball.

MEASUREMENTS OF *MASTIGOTEUTHIS* (?) *FAMELICA*.

	mm.		mm.
Tip of body to tip of ventral arms.....	64	Width of head.....	4
Tip of body to base of dorsal arm.....	44	Length of—	
Tip of body to medio-dorsal margin of mantle.....	39	Head.....	5
Extreme length of fins.....	21	Dorsal arm.....	5
Length of fins at base.....	21	Second arm.....	6.5
Width across fins.....	14.5	Third arm.....	5.5
Width of mantle.....	4	Ventral arm.....	20

Type.—Catalogue no. 214314, United States National Museum [S. S. B. 260].

Type locality.—*Albatross* station 3989, 385 to 733 fathoms, bottom of coral sand and rock, vicinity of Kauai Island, June 11, 1902; a single specimen.

Material examined.—The type is unfortunately unique.

Remarks.—Although the whole aspect of this species is suggestive of *Chiroteuthis* rather than *Mastigoteuthis*, the short olfactory papilla and the apparent absence of photophores on either the eyes or the ventral arms preclude its reference to that genus as I had originally placed it. On the other hand, it seems to have little in common with the remarkable *M. agassizii* Verrill, which is the type species of the latter genus. Verrill's species is notable for the extremely rich development of photogenic organs over the entire outer integument, and possesses other features which induce me to believe that it will eventually prove generically distinct from almost all the more recently described species usually associated with it. Even from the latter forms the present species is strikingly different, and as the condition of the single specimen is confessedly not all that might be desired, besides being very likely immature, it may be that better material may after all accomplish its restoration to *Chiroteuthis*.

In purely superficial characters *M. famelica* seems nearer to *C. pellucida* Goodrich of the Bay of Bengal than to any other form of either genus known to me, but differs in the much larger fins, shorter neck, more poorly developed arms, and a number of other characters. Both species are remarkable for their gaunt slender body, and to this feature is due the specific name of the Hawaiian form.

Family CRANCHIIDÆ (Prosch 1847).

- Cranchidæ* Prosch 1847, p. 19.
- Cranchiadæ* Gray 1849, p. 37.
- Cranchiæformes* Steenstrup 1861 (*vide* Hoyle).
- Desmoteuthidæ* Verrill 1881, p. 300.
- Cranchiidæ* P. Fischer 1882, p. 340.
- Cranchiidæ* Pfeffer 1900, p. 154, 188.
- Cranchiidæ* Chun 1906, p. 82.
- Cranchiidæ* Pfeffer 1908, p. 63, 101.
- Cranchiidæ* Chun 1910, p. 299.
- Cranchiidæ* Pfeffer 1912, p. 636.

Mantle border firmly fused with the head in the nuchal region and with the base of the funnel on either side. Body usually membranous and transparent; nearly colorless. Eyes usually large, often pedunculate. Sessile arms with two rows of suckers only; tentacles with four rows of suckers, which frequently extend down the stalk for the greater portion of its length; hooks may occur on the tentacle club, but only in one or two genera. Photogenic organs may be numerous developed on the ventral aspect of the eyeball, may occur within the pallial chamber, or may be entirely absent.

Genus *LIOCRANCHIA* Pfeffer 1884.

- Liocranchia* Pfeffer 1884, p. 25.
- Liocranchia* Chun 1906, p. 84.
- Liocranchia* Chun 1910, p. 303, etc.
- Liocranchia* Pfeffer 1912, p. 644, 665.

Mantle thin, saccular; often much inflated. Fins of rounded outline, terminal, small to moderate in size. Two diverging series of small conical cartilaginous tubercles extend back from the ventral point of fusion of the mantle and funnel on either side; in some forms a similar series may be present

along the medio-dorsal line of the mantle. Eyes large, sessile; a row of four large oval photophores on the ventral aspect. Left ventral arm hectocotylized.

Type.—*Liocranchia Brockii* Pfeffer 1884 (species first named)=*L. reinhardtii* (Steenstrup), a species of very wide distribution.

Liocranchia globulus Berry 1909. (Pl. LIII, fig. 2-4.)

Cranchia (*Liocranchia*) *globula* Berry 1909, p. 415, 419, fig. 9.

Liocranchia reinhardtii (pars) Chun 1910, p. 336, 337.

Liocranchia globulus Pfeffer 1912, p. 666, 674.

Animal small, pelagic. Body almost completely spherical; short, rounded, the maximum diameter almost but not quite equal to the length; mantle truncate in front, suddenly constricted posteriorly and tapering rapidly to an acute point which forms the base of attachment for the fins. Mantle mainly smooth; very thin and membranous; anterior margin passing in three even nearly equal curves from each point of attachment to the next; the latter three in number and about equidistant, the ventral points of fusion with the base of the funnel being about as far separated from one another as either is from the nuchal attachment. At the extreme mantle margin the position of each point of attachment is marked externally by a series of small projecting cartilaginous tubercles of acutely conical shape; the dorsal series is a close succession of at least 48 tubercles in single file, forming a narrow cartilaginous ridge along the anterior two-thirds of the medio-longitudinal line, a wedge-shaped area forming the posterior continuation of this ridge being hyaline and bare; the ventral series are each double, forming a Λ -shaped ridge having its apex at the margin, and with about 20 minute tubercles of two sizes in more or less irregular alternation in each line, flanked at the anterior end by parallel rows of two or three smaller tubercles on each side (pl. LIII, fig. 2). The divergence between the diverging arms of these ventral series is somewhat less than 90 degrees.

Fins small, thin; very short and broad, so that the outline of each is roughly circular; separated only by the minute posterior protrusion of the mantle, beyond which they extend for perhaps a third of their length; base of attachment only about one-half the total length.

Head minute; exceedingly short and broad; little projecting beyond the mantle. Eyes large, prominent; lid apertures very small, constricted; a series of four rather large oval photophores is visible on the inner ventral periphery upon the removal of the outer integument; they are subequal in size, very closely placed, and to all appearances essentially similar under a low power lens. A very large transparent fingerlike "olfactory papilla" has its origin from the outer integument just back of the eyelid opening. Funnel short, broad, well projecting beyond the mantle, and with a noticeable ventral flexion not far from the tip.

Arms short, poorly developed; unequal, the relative order of length 3, 4, 2, 1; dorsal pair decidedly the shortest and weakest, bearing only 6 to 8 pairs of suckers (largest near the base); second and fourth pairs more nearly equal, each second arm with about 9 pairs of suckers; third pair much the largest and longest, bearing 12 or more pairs of suckers. Umbrella present but poorly developed; extending between the dorsal arms for nearly half their length, and not exceeding this width between any of the arms; apparently absent between the arms of the ventral pair, and nearly so between these and the third pair. Suckers exceedingly minute, pedunculate; in two regularly alternating rows; horny rings apparently smooth, but this feature is somewhat difficult to ascertain.

Tentacles stout, smoothly cylindrical, much thicker and heavier than the arms; nearly as long as the mantle. Clubs little expanded, tapering to a bluntish point, lightly keeled, and furnished with a narrow delicate swimming membrane along each margin. Suckers minute, pedunculate; on the club in four rather crowded rows; largest near the middle of the club, very minute distally, and also proximally, where they gradually become more widely spaced, each row in the meanwhile tending to press in toward the center, so that there soon appear to be but two rows which continue down the stalk for about two-thirds of its entire length;^a aperture of suckers small; horny rings apparently smooth, but surrounded by radial papillae.

^a In the smallest specimen these suckers extend practically to the base of the stalk.

Color of preserved specimens a semitranslucent grayish white, probably colorless or opalescent in life. Chromatophores light brown in color; few in number; minute; most evident are a number of very small ones scattered over the posterior portion of the ventral surface of the mantle in advance of the fins; there is also a transverse series forming a slightly irregular semicircle on the ventral aspect a little distance back of the mantle margin. Two longitudinal series of distantly placed chromatophores extend along each tentacle.

MEASUREMENTS OF *LIOCRANCHIA GLOBULUS*.

Number in author's register.....	262	282	Number in author's register.....	262	282
	mm.	mm.		mm.	mm.
Total length (mantle distended).....	45	22	Width across fins.....	7	4
Tip of body to tip of third arms (mantle distended).....	26	14	Width of head.....	4.5	.....
Dorsal length of mantle, exclusive of fins (distended).....	20	11	Length of—		
Dorsal length of mantle, exclusive of fins (not distended).....	25	.....	Head.....	2	.....
Maximum width of mantle (distended).....	19	10	Dorsal arms.....	1	.....
Extreme length of fins.....	4	2	Second arms.....	1.5	.....
Length of fins at base.....	2	.....	Third arms.....	3	.....
			Ventral arms.....	2	.....
			Tentacle.....	19	9
			Tentacle club.....	4	.....

Type.—Catalogue No. 214315, United States National Museum [S. S. B. 262].

Type locality.—*Albatross* station 3878, surface, south of Lanai and west of Kahoolawe, April 14, 1902; two specimens.

Distribution.—Hawaiian Islands (*Albatross*).

SPECIMENS OF *LIOCRANCHIA GLOBULUS* EXAMINED.

Number of specimens.	Locality.	Depth.	Collector.	Remarks.	Author's register.
1	Off Molokini Islet, south of Lanai and west of Kahoolawe.	Surface....	Albatross station 3878.....	U. S. Nat. Mus., Cat. 214315; type.	262
1	.....do.....	.....do.....	.....do.....	Cotype.....	282
1	Between Kauai and Oahu.	.....do.....	Albatross station 4009.....	.....	263

Remarks.—Should this curious form prove to be a valid species, it adds one further member to the very remarkable group of aberrant squids which comprise the family *Cranchiidae*. The inflated saccular mantle here reaches practically the greatest attainable maximum of rotundity, so that a specimen looks not unlike a bubble having a few appendages of small size at either pole. The nearest ally of our species is self-evidently the *L. reinhardtii* (Steenstrup), with which indeed it is united by Chun, but the latter possesses the characteristic inflation only in vastly less degree. Lönnberg (1897, p. 611) has considered rotundity to be a condition in *L. reinhardtii* attendant upon immaturity and has given figures of an unusually large specimen which is almost loliginiform. However, the largest of the *Albatross* specimens is no whit less spherical than the youngest, and in this feature no figures or measurements of *L. reinhardtii* which I can find on record show close approach to any of them. On the other hand our knowledge of the limits of variation in these forms, either living or after preservation, is still very far from complete, and Chun's suggestion that this extreme state of inflation is due to a sharp contraction of the circular muscles around the mantle opening at the moment the animals were killed may prove to be the true explanation. Should this be so, it is somewhat curious that all three of the specimens before me chanced to be overwhelmed by the preserving fluid at exactly the same moment of contraction. It is believed that the drawings show the true condition with a very fair degree of accuracy, as in each case the mantle of the specimen was carefully distended by means of a pipette without the exertion of undue pressure, and an attempt was even made to keep the specimens so inflated suspended freely in the alcohol while the more important measurements were being taken.

In all other respects the Hawaiian form is essentially similar to *L. reinhardtii* except that (1) the number of cartilaginous tubercles in the dorsal series is somewhat less than given by Lönnberg for the specimen described by him, although more numerous in the ventral series; (2) the fins are conspicuously smaller; and (3) according to Pfeffer the statement that the latter are "flanked near the anterior end by parallel rows of two or three smaller tubercles on either side" does not hold with respect to the older species.

Genus *MEGALOCRANCHIA* Pfeffer 1884.

Megalocranchia Pfeffer 1884, p. 24.

Desmoteuthis Pfeffer 1900, p. 191 (not of Verrill 1881).

Desmoteuthis Chun 1906, p. 85.

Desmoteuthis Chun 1910, p. 304, 356.

Megalocranchia Pfeffer 1912, p. 645, 711.

Megalocranchia Berry 1912c, p. 644

Body cask-shaped, membranous, transparent, very weakly pigmented. Fins oval, longer than broad, overreaching the extremity of the body. Eyes large, rotund, protruding, sessile; on the ventral surface of each a very large semicircular photogenic organ, with a smaller crescent-shaped organ just in front. Arms with two rows of suckers; tentacles with four rows of suckers which extend along the greater portion of the stalk; none of the suckers modified into hooks; no fixing apparatus. Photogenic organs wanting except on the eye as stated.

Type.—*Megalocranchia maxima* Pfeffer 1884 (monotypic); described from the Cape of Good Hope.

Megalocranchia fisheri (Berry 1909) Pfeffer 1912. (Pl. LIII, fig. 5, 6; pl. LV, fig. 2.)

Helicocranchia fisheri Berry 1909, p. 417.

Xenoteuthis fisheri Berry 1909, p. 419 (error).

Megalocranchia fisheri Pfeffer 1912, p. 718.

Megalocranchia fisheri Berry 1912c, p. 644.

Animal small, body somewhat barrel-shaped. Mantle smooth, tough, membranous, saccular, thin, very much inflated; largest at a point nearly midway between the head and fins; somewhat tapering anteriorly and to a greater degree posteriorly, where it becomes at last suddenly constricted, terminating in a short, slender, spitlike point extending between the fins and serving as their base of attachment; maximum width of mantle probably about half its length.^a

Fins rather small, thin; each semicircular, almost exactly half as wide as long, and a little over a quarter the length of the mantle; almost continuous posteriorly and separated along the median line only by the thread of integument covering the slender hinder extremity of the gladius.

Head very short and broad; slightly concave above and below; relatively very large, due to the enormous globular eyes which are only faintly constricted at the base; lid openings very small, puckered, so elevated as to appear almost papilliform. Mantle attached firmly to the head in the nuchal region and also to the base of the funnel on either side. Funnel large, thin-walled, conical, broad at the base; extremity not quite reaching the base of the ventral arms; aperture ample, with a caplike upper lip. Funnel organ difficult to distinguish with certainty.

Arms short, robust, fleshy, the longest less than one-third the length of the mantle; unequal, the order of length 3=4, 2, 1; umbrella wanting; all the arms outwardly keeled and provided with a very delicate trabeculated marginal membrane, which attains by far its best development on the arms of the third pair; the latter in every way larger than the others and with larger suckers. Suckers biserial, closely placed, regularly alternating to the tip; oblique, hood-shaped; apertures wide; horny rings (at least on third arms) scarcely dentate, but very minutely and beautifully crenulate on the upper border, nearly smooth below.

^a The mantle is much wrinkled and contracted in this specimen, especially ventrally (where the distance from the tip of the body to the mantle margin is much less than it is dorsally), thus precluding the possibility of accurate measurement or exact statement of relative proportions. This condition is probably wholly due to the action of the preserving fluid.

Tentacles rather short, stout, about twice as long as the arms, as compared with which they are larger and heavier in every way; stalks nearly cylindrical. Clubs large, well expanded; bordered by a narrow frill-like web or keel along either margin of the sucker-bearing area, supplemented dorsally by a wider gracefully crenulate membrane which has its origin outside the former and lies parallel to it along the distal two-thirds of the club. Suckers small, in four distinct but rather crowded rows on the club; the two median series slightly the larger, but the suckers in all four rows attaining their maximum near the middle of the club; distally they gradually diminish in size, and also proximally, where they steadily become more widely spaced, extending down the flattened inner surface of the stalk for about half its length (exclusive of the club); the four-rowed condition really persists throughout, but on account of the tendency of the various series to press in toward the center at the same time with the increase in interspacing of the suckers, the arrangement soon appears to be biserial and maintains this appearance throughout most of the length of the stalk. Proximal to the point where the marginal membrane of the club comes to an end some 20 to 23 of these alternating pairs of suckers may be counted. Horny rings of the larger suckers minutely dentate on the upper margin with 12 to 14 sharp-curved elongate teeth, which become nearly or quite obsolete below.

Color of preserved specimen a soiled semitranslucent white. Chromatophores very minute and sparsely distributed; they apparently exhibit no very definite arrangement.

Two large photogenic organs form a conspicuous brownish patch nearly covering the ventral surface of each eyeball and visible even through the outer integument which overlies them. The larger is roughly semicircular in outline, its flatter anterior margin somewhat concave, and with the convex side of the crescent-shaped smaller organ closely applied within it. The outline of both organs is in the main similar to those of *D. pellucida* as figured by Chun, but considerably more elongate.

MEASUREMENTS OF *MEGALOCRANCHIA FISHERI*.

	mm.	Length of—	mm.
Total length.....	73	Right second arm.....	8
Length of mantle (dorsal).....	47	Left second arm.....	8
Maximum width of mantle.....	23	Right third arm.....	13
Extreme length of fins.....	12.5	Left third arm.....	12
Width across fins.....	12.5	Right ventral arm.....	12
Length of head (median).....	4	Left ventral arm.....	12.5
Width of head across eyes.....	15	Tentacle.....	27
Length of—		Sucker-bearing area of tentacle.....	18
Right dorsal arm.....	6	Tentacle club.....	8
Left dorsal arm.....	6	Funnel.....	8

Type.—Catalogue No. 214316, United States National Museum (S. S. B. 106).

Type locality.—Albatross station 3883, 277 to 284 fathoms, bottom of globigerina ooze, off Mokuhooniki Islet, Pailolo Channel, April 16, 1902; one specimen.

Distribution.—Hawaiian Islands (*Albatross*).

Material examined.—The type is unique.

Remarks.—This species is a typical *Megalocranchia*, showing exceedingly close affinity to both the *M. maxima* Pfeffer and the more recently described *M. pellucida* (Chun). The latter species is peculiar in that the horny rings of the tentacular suckers are bluntly toothed, lacking the long acute teeth which are characteristic of both the other species. The following rather trivial features distinguish *M. fisheri* from *M. maxima*: (1) The longer tentacles. (2) The longer ventral arms. In his description of *M. maxima* Pfeffer says regarding the arms that "4 und 2 sind wenig verschieden," while in the present species the disproportion between the arms of these pairs is conspicuous. In my first diagnosis I gave the arm formula as 4, 3, 2, 1. In reality this is true of the left side only, the right arms standing 3, 4, 2, 1, but in both cases the difference between the third and ventral arms is so slight as scarcely to be worth

mentioning, so that the formula is perhaps preferably stated as $3=4, 2, 1$. (3) The horny rings of the tentacular suckers have 12 to 14 instead of 10 teeth on the upper margin. These are none of them very great differences, but seem sufficient, together with the widely separate habitats of the two forms, to render their union unjustifiable until a better representation of each is available for study.

My original reference of this species to *Helicocranchia* was certainly ill advised, our species differing conspicuously in the larger, more elongate nonpedunculate fins, spitlike posterior continuation of the mantle, much smaller funnel, and very much larger unstalked eyes.

The discovery of this species very greatly extends the known geographical range of the little group of typical *Megalocranchia*, but even yet the distribution of the various species is of interest because of the continuity of the respective regions occupied by them. Beginning with *M. pellucida* in the south Atlantic, the remaining species form a geographic chain extending more than halfway around the globe. *M. maxima* is known only from the Cape of Good Hope, *M. abyssicola* Goodrich from the waters of the Indian peninsula, and the present species from the Hawaiian Islands. Because of its occupancy of so distant and isolated a region, the Hawaiian species might be expected to be the most highly differentiated member of the group, but such is very far from being the case. On the other hand *M. abyssicola* seems in many ways peculiar and not so closely allied to any of the other three forms as they are to one another.

It has been a pleasure to associate with this interesting species the name of my friend, Dr. Walter K. Fisher, who, as a member of the staff of the *Albatross* during the Hawaiian explorations, had no small part in the duties of caring for and preserving the present material.

Genus *HELICOCRANCHIA* Massy 1907.

Helicocranchia Massy 1907, p. 382.

Helicocranchia Massy 1909, p. 34.

Desmoteuthis (pars) Chun 1910, p. 302, 357.

Teuthowenia (*Helicocranchia*) Pfeffer 1912, p. 742, 750.

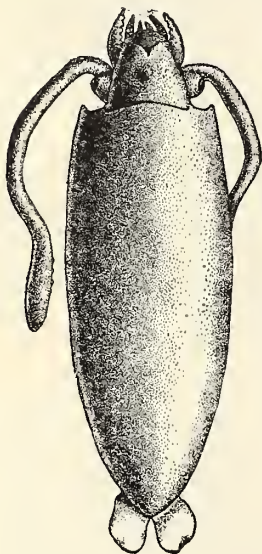


FIG. 40.—*Helicocranchia* sp., ventral view of specimen [261] from the vicinity of Kauai, partially restored. $\times 2$. In this figure the mantle is scarcely represented as sufficiently elongate and the arms are probably shown as much too short and stocky.

Body elongate, bag shaped. Fins small, oval; narrowed or even pedunculate at base; little or not at all united posteriorly. Eyes large, elevated on short stalks. Arms rather long, with two rows of suckers; no hooks. Funnel enormous, extending well past the head and eyes.

Type.—*Helicocranchia Pfefferi* Massy 1907 (monotypic); described from off the coast of Ireland.

Chun has referred this genus to *Desmoteuthis* (i. e., *Megalocranchia*), but it seems to me to be rather nearer to *Owenia* (*Teuthowenia* Chun), from which it differs most conspicuously in the more rounded eyes and enormous development of the funnel.

Helicocranchia species?

Cranchiid species, Berry 1909, p. 419 (mere locality record).

A single sadly dilapidated specimen of some cranchiid approaching very close to this genus was taken at *Albatross* station 4001, 230 to 277 fathoms, off Kapuai Point, Kauai [S. S. B. 261]. It is too fragmentary for satisfactory determination, but has been made the subject of the following notes:

Mantle much wrinkled and distorted; its outline in general elongate, swollen, cask-shaped; tapering behind to a point; anterior margin fused with head in the nuchal region and on either side of the funnel as usual in the group; width of mantle about a third the length. Fins very small, separate, delicate; attached for the anterior half of their inner margins to the minute and sharp membranous point which forms the posterior termination of the mantle.

Head small. Eyes moderately small, projecting forward upon very short club-shaped stalks. Funnel enormous, reaching far beyond the head and more conspicuous than any other structure in the anterior region of the body; heavy walled and inflated; aperture large.

Sessile arms very slender and delicate; the third pair much the longest, the second pair next in length, and the dorsal and ventral pairs very minute. Suckers small, but not in relation to the size of the arms; biserial; umbrella and swimming membranes absent.

Tentacles decollated; the stumps heavy, fleshy, brittle, without traces of suckers.

MEASUREMENTS OF *HELICOCRANCHIA* SPECIES?

	mm.		mm.
Length of mantle, dorsal.....	36	Length of dorsal arm.....	4
Width of mantle.....	11 ?	Second arm.....	9
Extreme length of fins.....	4	Third arm.....	11
Length of fins at base.....	2	Ventral arm.....	4
Width across fins.....	7	Funnel along medio-ventral line.....	9.5

The specimen is minus the major portion of both tentacles, the eyes and arms have become detached (although preserved in the bottle), and the remaining portions otherwise mutilated, so that it does not seem wise to attempt to attach any specific name, although a new species is undoubtedly represented. The great resemblance in general form to *Helicocranchia pfefferi* as described and figured by Miss Massy (1909, p. 34) is such that I have little hesitation in assuming that the present specimen is referable to the same genus, although the more broadly attached fins, lack of suckers on the stumps of the tentacles, and various minor details indicate that at any rate the two are not conspecific. If this identification be correct, the genus is now reported for the first time from the Pacific, the type species being known only from a single specimen dredged off the coast of Ireland. Were it not for the immense funnel the aspect would be almost that of an *Owenia*. The accompanying drawing is very unsatisfactory because of the difficulty and uncertainty pursuant to any endeavors to straighten out the wrinkled mantle and reconstruct fragmentary parts, but it seems worth while to offer it for whatever it may be worth. The mantle is probably not represented as sufficiently elongate, and the arms are considerably too short and stout.

LARVAL OEGOPSID.

An undetermined larval oegopsid of minute size is in the collection from *Albatross* station 3803, from a depth of 50 fathoms, between the Erben Bank and Kaiwi Channel [S. S. B. 387].

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TABLE IV.

STATIONS AT WHICH CEPHALOPODS WERE TAKEN DURING THE 1902 HAWAIIAN CRUISE OF THE "ALBATROSS", WITH AN INVENTORY OF THE SPECIES COLLECTED AT EACH.

Station number.	Locality.	Date (1902).	Depth.	Surface temperature.	Bottom temperature.	Character of bottom.	Species taken and number of specimens.
3799	29° 22' N., 139° 31' W., between Erben Bank and Kaiwi Channel.	Mar. 18	Fathoms. Surface.	° F. 65	° F.		4 Tremoctopus violaceus.
3802	27° 4' 15" N., 144° 18' 30" W., between Erben Bank and Kaiwi Channel.	Mar. 20	150				1 larval Octopod.
3803	25° 39' 45" N., 142° 41' 45" W., between Erben Bank and Kaiwi Channel.	Mar. 21	50				1 larval Decapod.
3821	South coast of Oahu.	Mar. 31	Surface.	76			1 Polypus β , 1 Euprymna scolopes.
3829	Off Avalu Point, Lanai.	Apr. 1	Surface.	75			1 Euprymna scolopes.
3832	South Coast of Oahu.	Apr. 2	153-142	76		Brown mud, sand.	1 Stoteuthis iris.
3837	South coast of Molokai.	Apr. 3	Surface.	76			1 Polypus β .
3843	do.	Apr. 4	Surface.	75			1 Polypus α .
3846	do.	Apr. 8	Surface.	76			1 Euprymna scolopes.
3849	do.	do.	Surface.	76			1 Polypus γ .
3856	Pailolo Channel between Maui and Molokai.	Apr. 9	127	74	66.5	Fine sand, yellow mud.	1 Euprymna scolopes, 1 Scaergus patagiatus.
3857	do.	do.	127-128	74	62.5	do.	1 Argonauta sp., 1 Euprymna scolopes.
3858	do.	do.	128-138	74	61.5	Fine sand, gray mud.	1 Scaergus patagiatus.
3859	do.	do.	138-140	74	60.2	Fine sand, mud.	1 Euprymna scolopes.
3865	do.	Apr. 10	256-283	76	45	Fine volcanic sand, rock.	1 Ommastrephes hawaiiensis.
3878	South of Lanai and west of Kahoolawe.	Apr. 14	Surface.	77			5 Tremoctopus violaceus, 7 Brachioeuthis riisei, 2 Liocranchia globula, 1 Megalocranchia fisheri.
3883	Pailolo Channel between Maui and Molokai.	Apr. 16	277-284	76	45.2	Globigerina ooze.	
3889	North coast of Molokai.	Apr. 17	Surface.	74			3 Euprymna scolopes, 1 Rhyncoteuthion α .
3896	Auau Channel between Maui and Lanai.	Apr. 29	126-130	74	63.1	Sand, pebbles, broken shells.	1 Euprymna scolopes.
3898	Pailolo Channel between Maui and Molokai.	do.	258-284	74	44.1	Brown globigerina mud, fine sand.	1 Laetmoteuthis lugubris.
3900	do.	do.	283-280	75	43.9	do.	1 Heteroteuthis hawaiiensis.
3904	North coast of Molokai.	Apr. 30	Surface.	75			1 Laetmoteuthis lugubris.
3905	do.	do.	Surface.	75			2 Polypus β , 1 Polypus γ , 13 Euprymna scolopes.
3907	South coast of Oahu.	May 5	Surface.	75			1 Polypus β .
3911	do.	do.	Surface.	76			1 Polypus β .
3912	do.	do.	Surface.	76			1 Polypus β , 1 Rhyncoteuthion α .
3921	do.	May 6	Surface.	75			3 Polypus α , 2 Polypus β .
3926	21° 13' N., 158° 43' W., between Honolulu and Laysan.	May 10	Surface.	75			3 Tremoctopus violaceus, 1 Polypus β , 1 Euprymna scolopes, 1 Abralopsis (juv.), 5 Rhyncoteuthion α .
3927	21° 31' N., 161° 55' W., between Honolulu and Laysan.	May 11	Surface.	76			1 Argonauta böttgeri.
3929	23° 19' N., 166° 54' W., between Honolulu and Laysan.	May 13	Surface.	75			1 Tremoctopus violaceus.

TABLE IV—Continued.

Stations at which Cephalopods were taken during the 1902 Hawaiian cruise of the "Albatross", with an inventory of the species collected at each—Continued.

Station number.	Locality.	Date (1902).	Depth.	Surface temperature.	Bottom temperature.	Character of bottom.	Species taken and number of specimens.
			<i>Fathoms.</i>	<i>°F.</i>	<i>°F.</i>		
3930	25° 07' N., 170° 50' W., between Honolulu and Laysan.	May 15	Surface.	74			3 Tremoctopus violaceus, 1 Polypus β , 1 Rhyncoteuthion β .
3931	25° 27' N., 171° 08' W., between Honolulu and Laysan.	...do....	Surface.	74			2 Tremoctopus violaceus, 2 Euprymna scolopes.
3938	Vicinity of Laysan.....	May 16	148-163	76	60.3	White sand, broken shells.	1 Scaergus patagiatus.
3980	Between Honolulu and Kauai.	June 9	Surface.	77			1 Polypus β , 9 Euprymna scolopes, 1 Rhyncoteuthion α .
3989	Vicinity of Kauai.....	June 11	733-385	78	37.5	Coral sand, rock.....	1 Heteroteuthis hawaiiensis, 1 Teleoteuthis compacta, 1 Mastigoteuthis (?) famelica.
4001	....do.....	June 16	277-230	78	44.3	Coral sand.....	1 Helicocranchia sp.
4002	....do.....	....do....	230-53	78	47.1	Fine coral sand, globigerina, coral.	2 Polypus ϵ .
4009	Between Kauai and Oahu.	June 17	Surface.	76			1 Liocranchia globula.
4010	....do.....	....do....	Surface.	76			4 Tremoctopus violaceus, 5 Euprymna scolopes, 1 Rhyncoteuthion α .
4011	....do.....	....do....	Surface.	77			7 Tremoctopus violaceus, 1 Polypus β .
	Honolulu Reef, Oahu.....	(?)					10 Polypus marmoratus, 3 Polypus ornatus, 1 Polypus β , 2 Euprymna scolopes.
	Honolulu market.....	(?)					1 Polypus sp., 1 Sepioteuthis arctipinnis, 2 Ommastrephes hawaiiensis.
4039	West coast of Hawaii.....	July 10-11.	670-697	76	38.7	Gray mud, foraminifera.	1 Eledonella (juv.).
4071	Northeast and north coast of Maui.	July 19	52-56	76	72.9	Fine coral, volcanic sand, foraminifera.	1 Euprymna scolopes.
4073	....do.....	....do....	69-78	76	71.9	Coarse coral sand, foraminifera.	1 Euprymna scolopes.
4079	....do.....	July 21	143-178	76	60.8	Gray sand, foraminifera.	1 Scaergus patagiatus.
4082	....do.....	....do....	220-238	76	48.8	Gray sand.....	1 Ommastrephes hawaiiensis.
4086	....do.....	....do....	Surface.	76			2 Tremoctopus violaceus.
4087	Northeast approach to Pailolo Channel.	....do....	308-306	76	43.6	Fine gray sand.....	1 Abralia trigonura.
4088	....do.....	....do....	306-297	75	43.8	....do.....	1 Heteroteuthis hawaiiensis.
4089	....do.....	....do....	297-304	75	43.8	....do.....	1 Heteroteuthis hawaiiensis.
4095	....do.....	July 22	290-286	76	43.9	Brown mud, fine sand, globigerina.	1 Allopous molis.
4102	Pailolo Channel between Maui and Molokai.	July 23	122-132	79		Fine gray sand, foraminifera.	3 Euprymna scolopes.
4103	....do.....	....do....	132-141	78	61.7	Fine gray sand.....	3 Scaergus patagiatus, 1 Euprymna scolopes.
4105	Kaiwi Channel between Molokai and Oahu.	July 24	314-335	76	43.8	Fine coral sand, foraminifera.	1 Pterygioteuthis microlampas.
4110	....do.....	....do....	449-460	76	40.3	Gray sand.....	1 Polypus hoylei.
4117	Northwest coast of Oahu..	July 25	282-253	77	45.6	Coral sand, foraminifera.	1 Ommastrephes hawaiiensis.
4122	Southwest coast of Oahu...	July 26	192-352	79	64.6	Coarse coral sand, shells.	1 Abralia astrodicta.
4130	Vicinity of Kauai.....	Aug. 1	283-309	77	46.1	Fine gray sand.....	1 Polypus hoylei.
4132	....do.....	....do....	257-312	77	46.8	Fine gray sand, mud...	1 Polypus hoylei, 1 Ommastrephes hawaiiensis.
4152	Vicinity of Modu Manu....	Aug. 5	Surface.	79			2 Euprymna scolopes, 1 Rhyncoteuthion α .
4153	....do.....	....do....	Surface.	79			1 Euprymna scolopes.
4190	34° 39' 18" N., 132° 04' W., between Honolulu and San Francisco, Cal.	Aug. 27.	Surface.	69			3 larval histioteuthids, 1 Brachiototeuthis rusei.

EXPLANATION OF PLATES.

Except where otherwise stated in the context, all the drawings were prepared by Miss Lora Woodhead, of Stanford University. The photographs were made by J. H. Paine.

The numbers in brackets have reference to the author's register of examined specimens.

PLATE XLV.

Polypus marmoratus, dorsal view of large male from Honolulu, $\times \frac{7}{8}$; [174]. Drawn by R. L. Hudson.

PLATE XLVI.

Fig. 1. *Polypus ornatus*, dorsal view of a medium sized male from Honolulu, [179]. $\times \frac{3}{4}$.

Fig. 2. *Polypus ornatus*, tip of hectocotylized arm of same specimen [179]; as yet not well developed, $\times 12$.

PLATE XLVII.

Fig. 1. *Polypus hoylei*, ventral view of male, type, $\times \frac{3}{4}$; [166]. Drawn by R. L. Hudson.

Fig. 2. *Scaurgus patagiatus*, dorso-lateral view of male (type), $\times 1\frac{1}{2}$; [204]. Drawn by R. L. Hudson.

Fig. 3. *Scaurgus patagiatus*, tip of hectocotylized arm of same specimen, $\times 2\frac{1}{2}$; [204]. Drawn by R. L. Hudson.

PLATE XLVIII.

Fig. 1. *Scaurgus patagiatus*, hectocotylized portion of left third arm of male (type), $\times 7$; [204].

Fig. 2. *Polypus hoylei*, hectocotylized portion of right third arm of male (type), $\times 4$; [166].

Fig. 3. *Polypus hoylei*, region surrounding right eye of same specimen, showing the supraocular cirri, considerably enlarged; [166].

Fig. 4. *Polypus hoylei*, funnel of male from the vicinity of Kauai, laid open along the medio-ventral line to show the funnel organ, $\times 2\frac{1}{2}$; [176].

Fig. 5. *Argonauta böttgeri*, inner aspect of left second arm of female, $\times 2\frac{1}{3}$; [165].

Fig. 6. *Polypus marmoratus*, hectocotylized portion of right third arm of large male from Honolulu, $\times 7$; [174].

Fig. 7. *Polypus* β , left dorsal arm of small specimen from off the south coast of Oahu, $\times 5$; [194].

Fig. 8. *Polypus* β , dorsal view of specimen from off the south coast of Oahu, considerably enlarged; [195].

PLATE XLIX.

Fig. 1. *Latmoteuthis lugubris*, lateral view of mandibles of specimen from the Pailolo Channel, nearly natural size; [212]. Drawn by J. H. Paine.

Fig. 2. *Latmoteuthis lugubris*, apical view of same, same scale. Drawn by J. H. Paine.

Fig. 3. *Tremoctopus violaceus*, inner aspect of all arms of left side of female not quite adult, $\times 3$; [221].

Fig. 4. *Tremoctopus violaceus*, funnel of same specimen laid open along medio-ventral line, $\times 4$; [221].

Fig. 5. *Euprymna scolopes*, left tentacle club of male (type), inner aspect, greatly enlarged; [320].

Fig. 6. *Euprymna scolopes*, outer aspect of left dorsal arm of male (cotype) showing hectocotylization, much enlarged; [323]. The suckers of the innermost row along the basal portion of the arm are considerably larger than they should be in the figure.

Fig. 7. *Euprymna scolopes*, inner aspect of middle portion of same arm of same specimen, showing modified suckers, greatly enlarged; [323].

Fig. 8. *Euprymna scolopes*, right lateral arm of same specimen (several suckers missing from ventral row and not supplied in drawing), $\times 4$; [323].

PLATE L.

Fig. 1. *Stoloteuthis iris*, dorsal view of type, $\times 3$; [31]. Drawn by H. V. Poor.

Fig. 2. *Stoloteuthis iris*, tentacle club of type, inner aspect, greatly enlarged; [31].

Fig. 3. *Heteroteuthis hawaiiensis*, tentacle club of type (female), greatly enlarged; [30].

Fig. 4. *Heteroteuthis hawaiiensis*, large sucker from third arm of male from station 4088, greatly enlarged; [333].

Fig. 5. *Heteroteuthis hawaiiensis*, inner aspect of second right arm of type (female), $\times 4\frac{1}{2}$; [30].

Fig. 6. *Heteroteuthis hawaiiensis*, photogenic organs of specimen from station 4089, $\times 2\frac{1}{2}$; [333].

Drawn by J. H. Paine.

Fig. 7. *Heteroteuthis hawaiiensis*, lateral view of type (female), $\times 1\frac{3}{4}$; [30]. Drawn by H. V. Poor.

Fig. 8. *Heteroteuthis hawaiiensis*, ventral view of type (female), with mantle partially laid open to expose the locking cartilages and funnel, $\times 2$; [30].

PLATE LI.

Fig. 1. *Abralia astrosticta*, ventral view of type (female), $\times 2$; [171]. Drawn by H. V. Poor.

Fig. 2. *Abralia astrosticta*, inner aspect of right tentacle club of type, $\times 15$; [171]. Drawn by H. V. Poor.

Fig. 3. *Abralia astrosticta*, ventral view of right eye of type and surrounding region, $\times 3$; [171]. Drawn by H. V. Poor.

Fig. 4. *Abralia astrosticta*, dorsal view of type, $\times 1\frac{1}{2}$; [171]. The extremities of the fins are represented as curved under, their true outline being more as indicated by the dotted line. Drawn by H. V. Poor.

Fig. 5. *Abralia astrosticta*, ventral aspect of funnel, showing the distribution of the photogenic organs, $\times 5$; [171].

Fig. 6. *Abralia astrosticta*, fixing apparatus of left tentacle club of type, much enlarged; [171].

Fig. 7. *Abralia astrosticta*, lateral aspect of head and funnel of type, showing locking cartilage of left side of funnel, $\times 4$; [171].

Fig. 8. *Abralia astrosticta*, funnel of type laid open medio-ventrally to expose the funnel organ, $\times 4$; [171].

PLATE LII.

Fig. 1. *Pterygioteuthis microlampas*, ventral aspect of right eye of type and surrounding region, $\times 6$; [277].

Fig. 2. *Pterygioteuthis microlampas*, funnel locking cartilage, much enlarged; [278].

Fig. 3. *Pterygioteuthis microlampas*, inner aspect of left tentacle club of type, much enlarged; [227]. Drawn by J. H. Paine, from a mount in balsam.

Fig. 4. *Toleoteuthis compacta*, inner aspect of left tentacle club of type, $\times 16$; [238].

Fig. 5. *Toleoteuthis compacta*, inner aspect of right third arm of type, $\times 13$; [238].

Fig. 6. *Mastigoteuthis (?) famelica*, ventral view of head of type, $\times 5$; [260].

Fig. 7. *Mastigoteuthis (?) famelica*, ventral arm of type, inner aspect, $\times 5$; [260].

Fig. 8. *Mastigoteuthis (?) famelica*, dorsal view of type, $\times 2\frac{1}{2}$; [260]. Drawn by H. V. Poor.

PLATE LIII.

Fig. 1. *Rhyncoteuthion* α , dorsal view of well advanced specimen with free tentacles, from station 3926, $\times 2$; [255].

Fig. 2. *Liocranchia globulus*, anterior (apical) portion of left latero-ventral series of tubercles, showing the small flanking tubercles (type), much enlarged; [262].

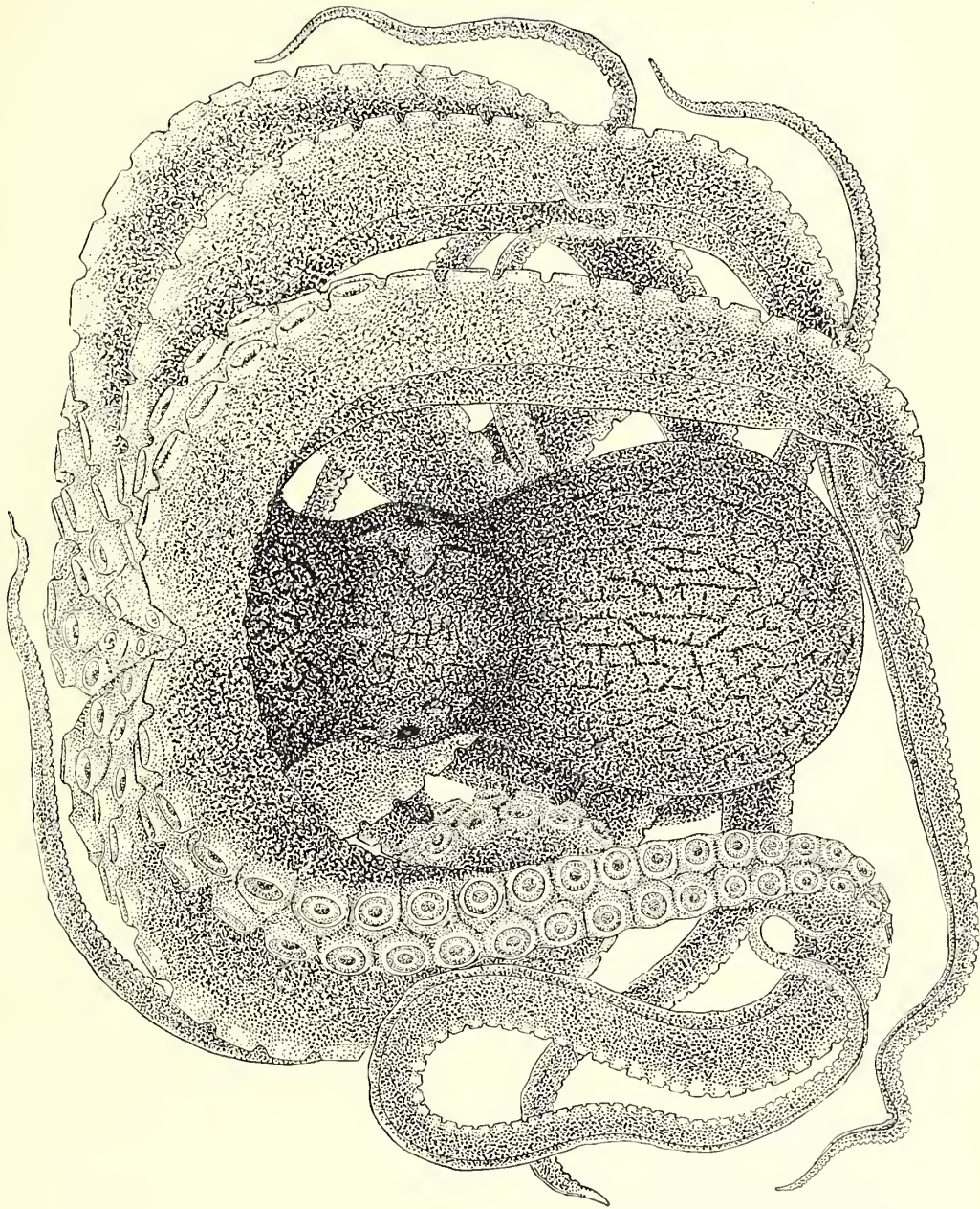
- Fig. 3. *Liocranchia globulus*, tentacle of type, $\times 8$; [262].
Fig. 4. *Liocranchia globulus*, dorsal view of type, $\times 2\frac{3}{4}$; [262]. Drawn by H. V. Poor.
Fig. 5. *Megalocranchia fisheri*, inner aspect of right tentacle club of type, $\times 4$; [106].
Fig. 6. *Megalocranchia fisheri*, lateral aspect of same, $\times 4$; [106].

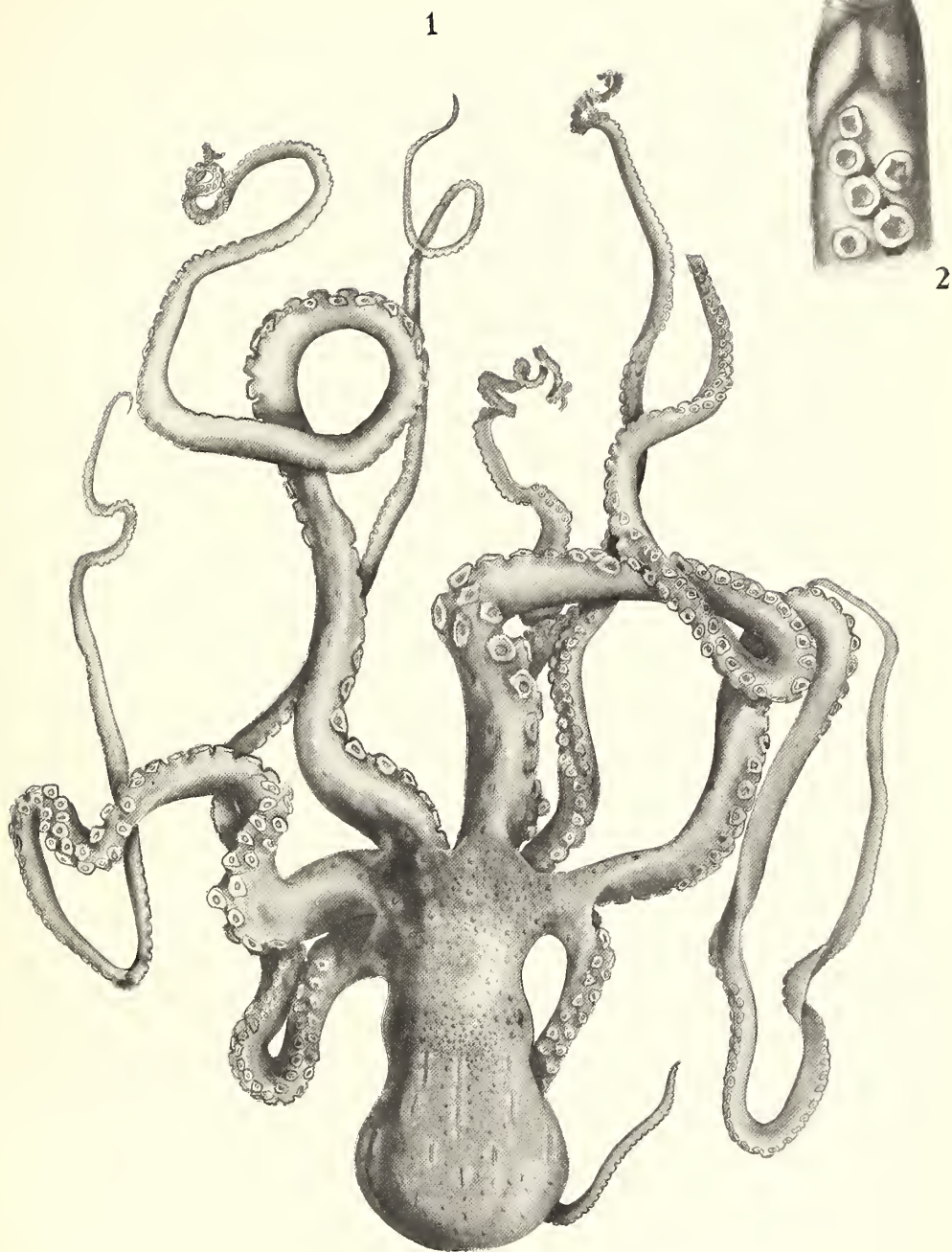
PLATE LIV.

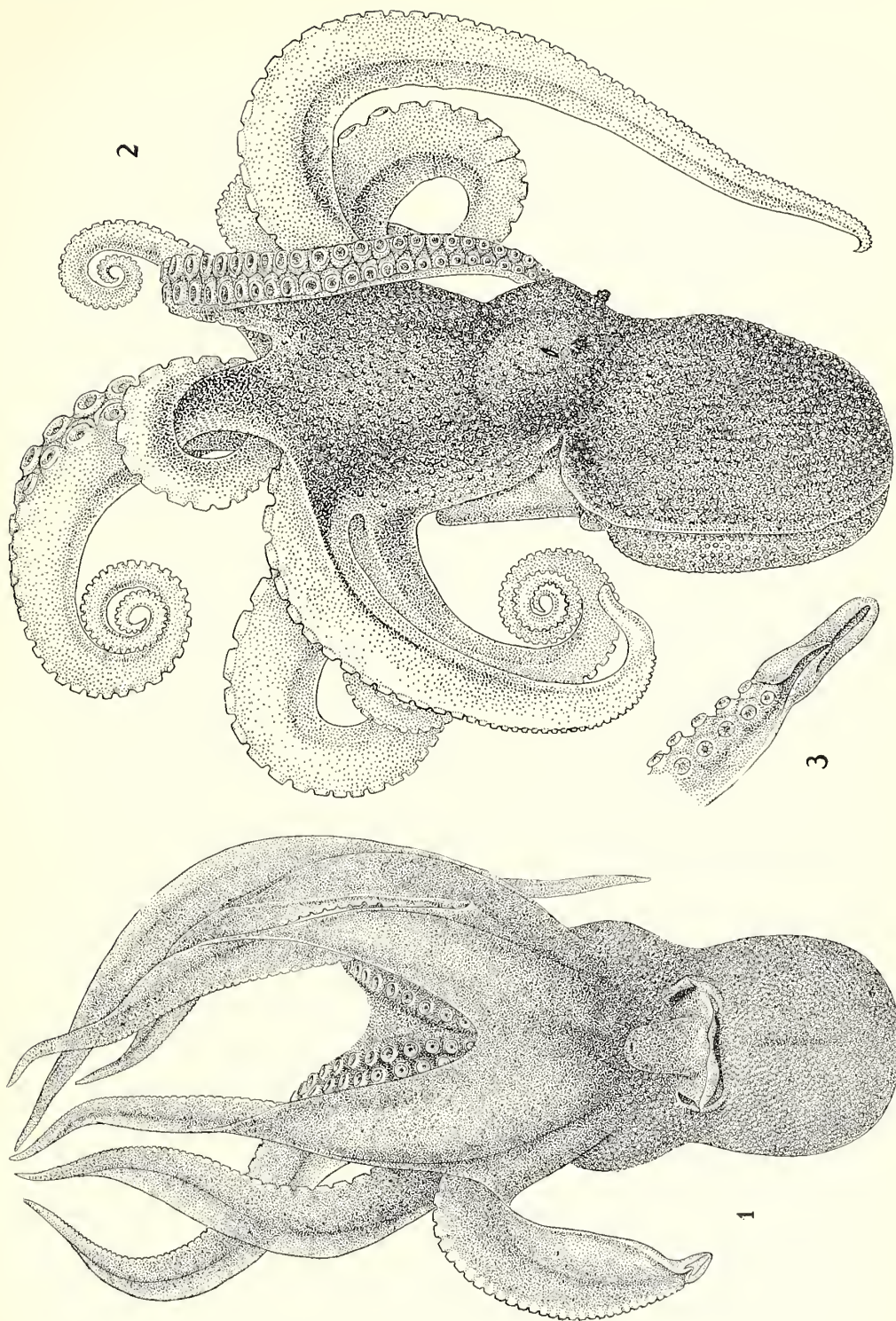
- Fig. 1. *Sepioteuthis arctipinnis*, ventral view of male from market at Honolulu, $\times \frac{1}{2}$; [42]. Photograph.
Fig. 2. *Ommastrephes hawaiiensis*, inner aspect of right third arm of type, $\times 1\frac{2}{3}$; [243]. Photograph.

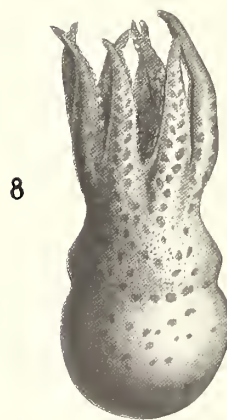
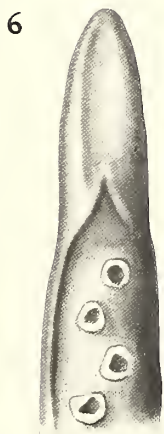
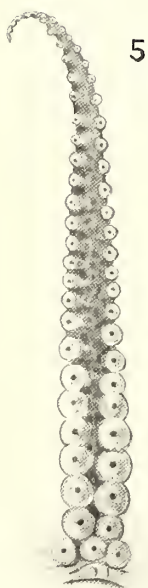
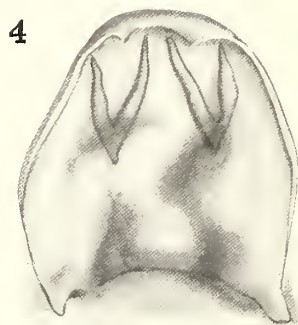
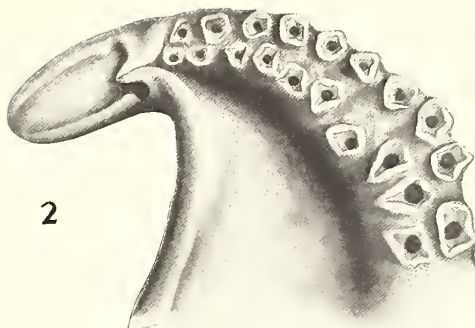
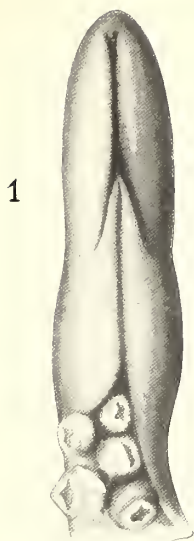
PLATE LV.

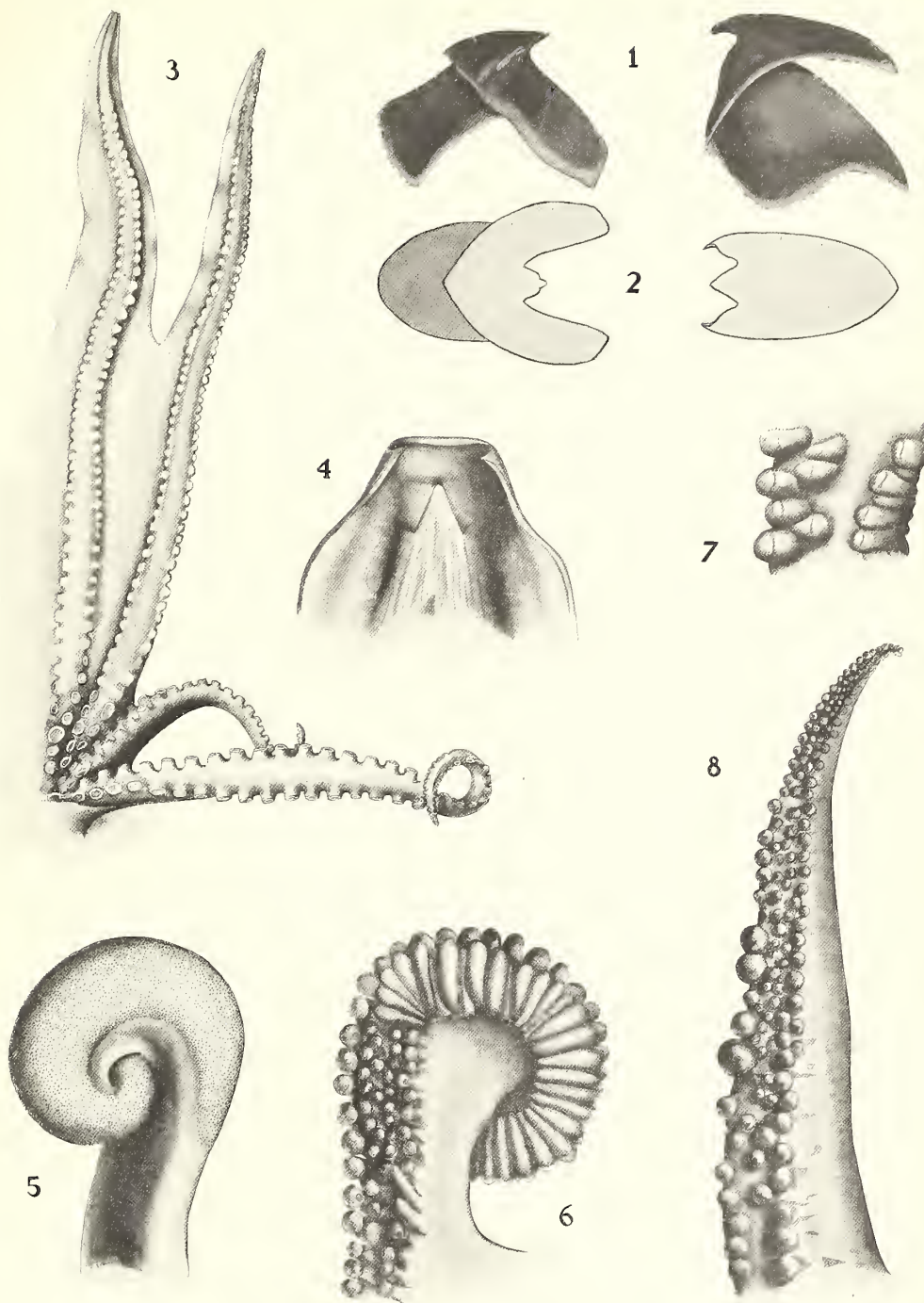
- Fig. 1. *Polypus hoylei*, inner aspect of arms and umbrella of type (male), $\times \frac{1}{2}$; [166]. Photograph.
Fig. 2. *Megalocranchia fisheri*, ventral view of type, $\times 1\frac{2}{3}$; [106]. Photograph.

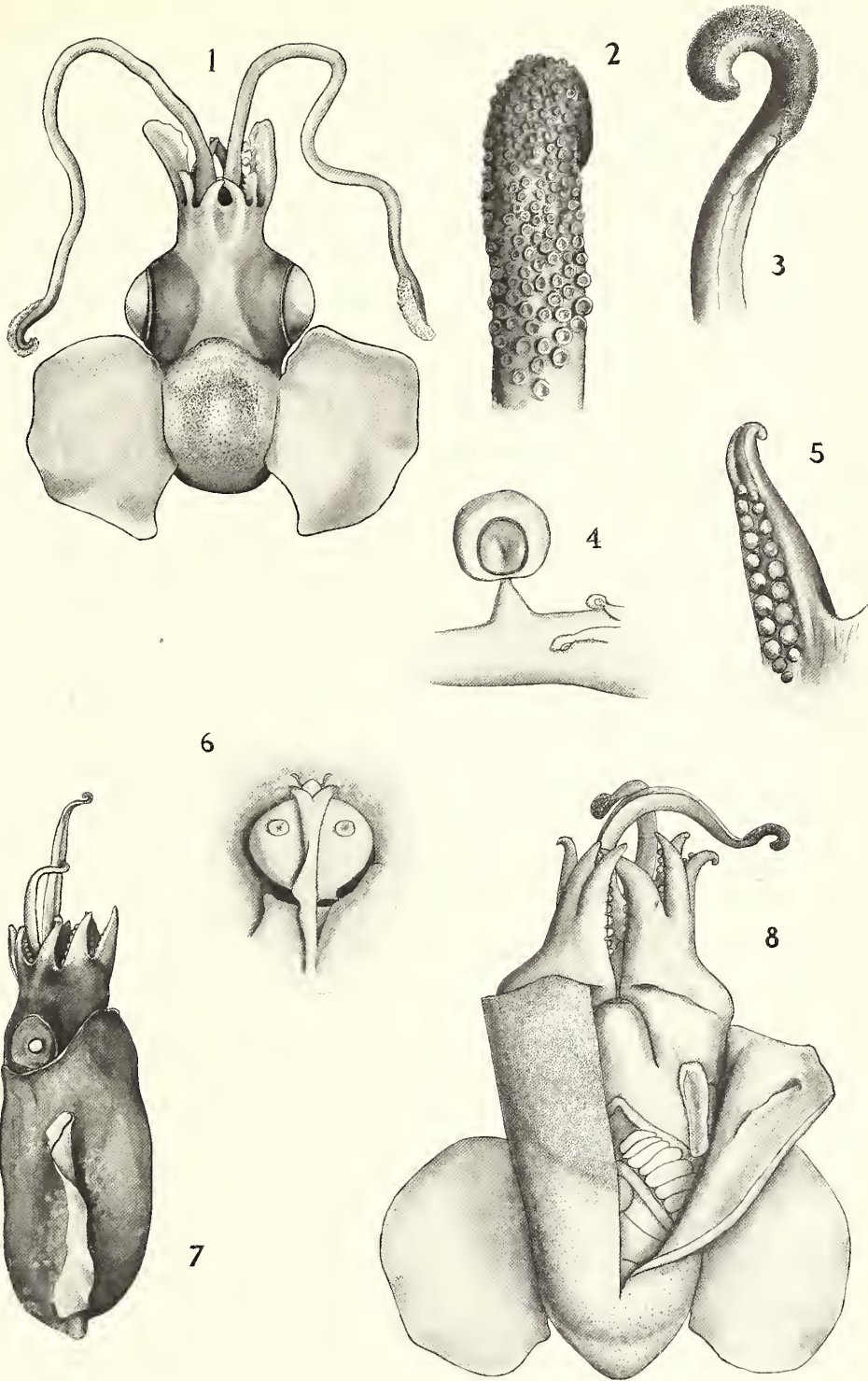


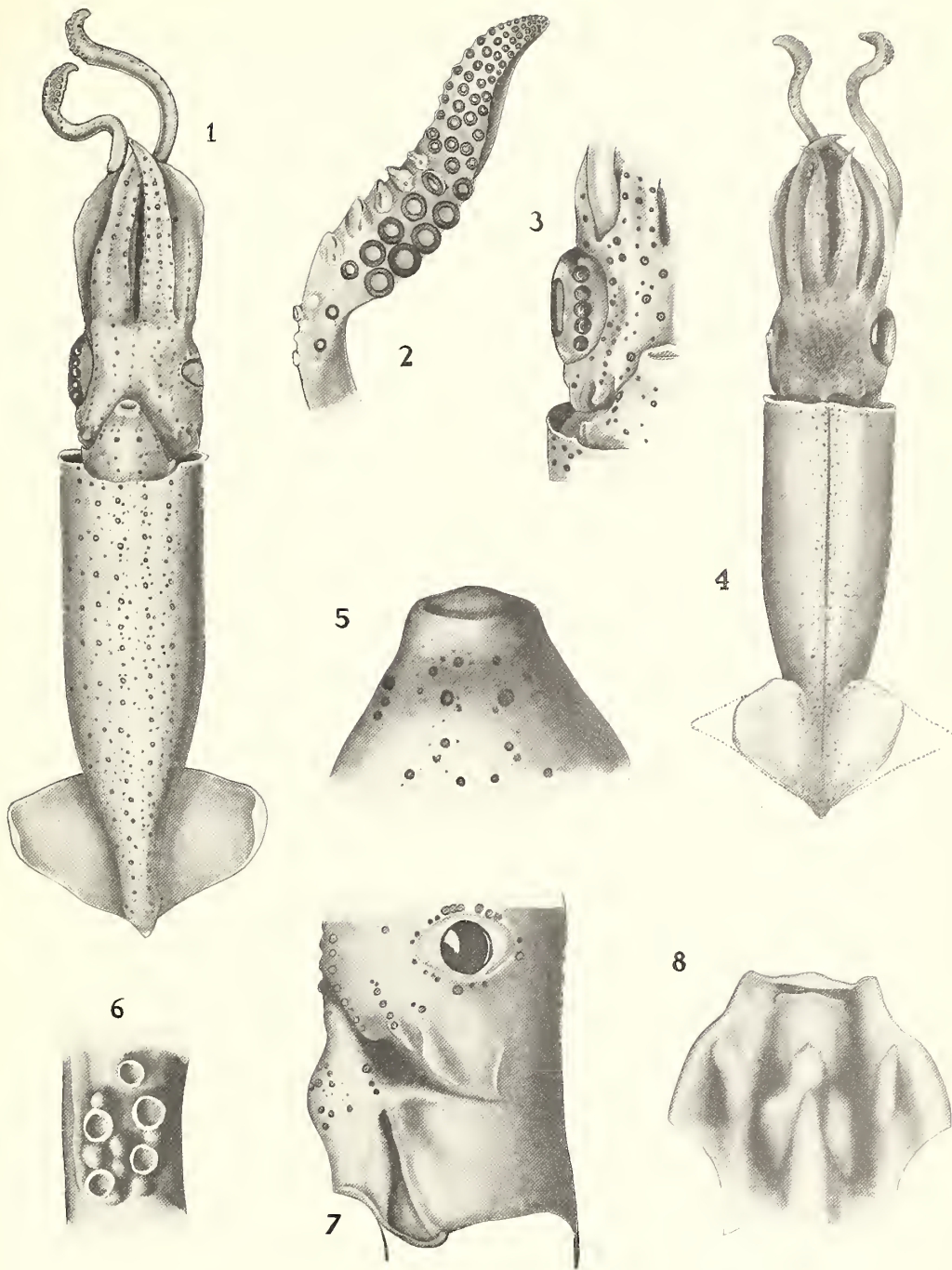


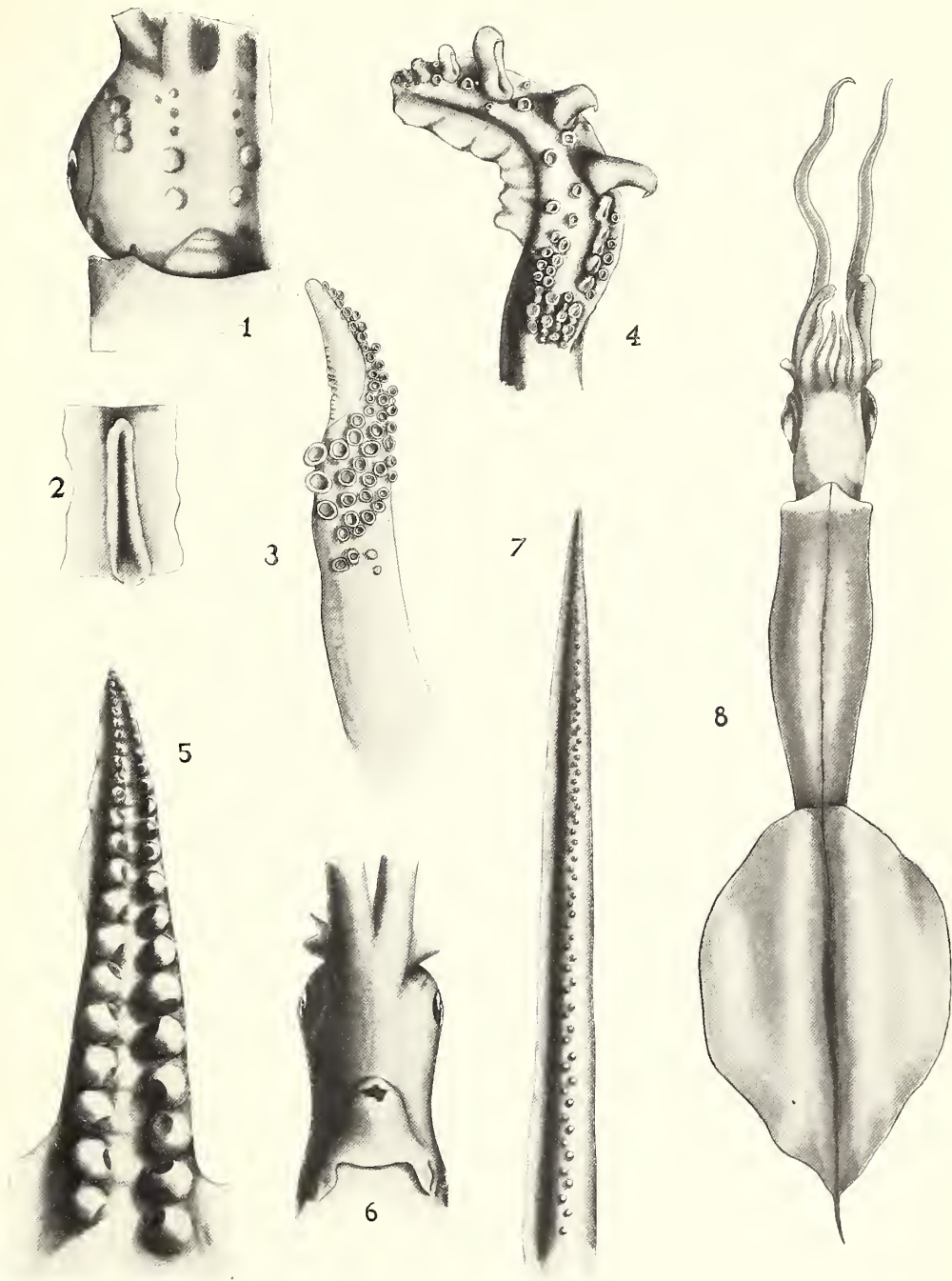


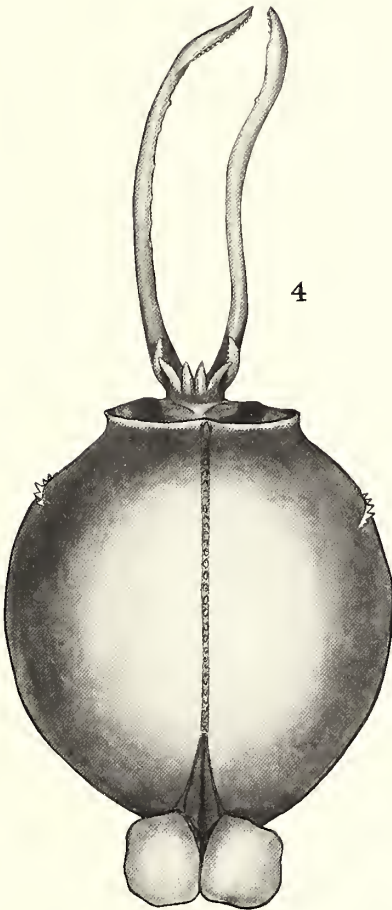
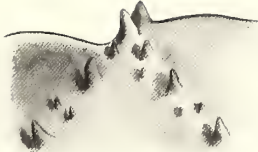


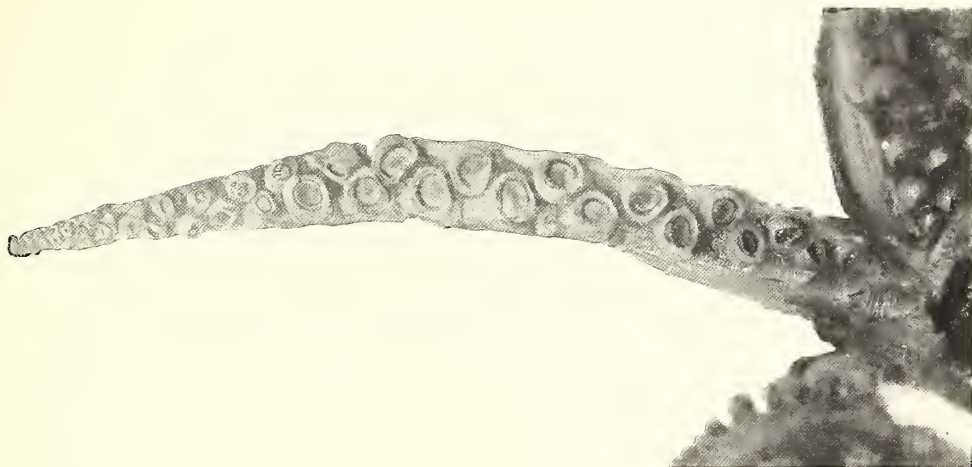




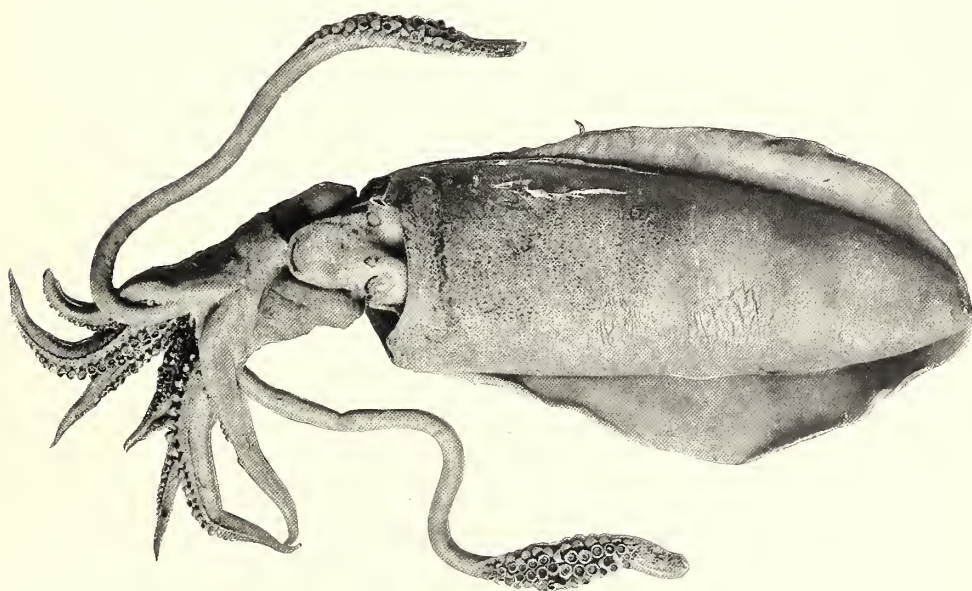




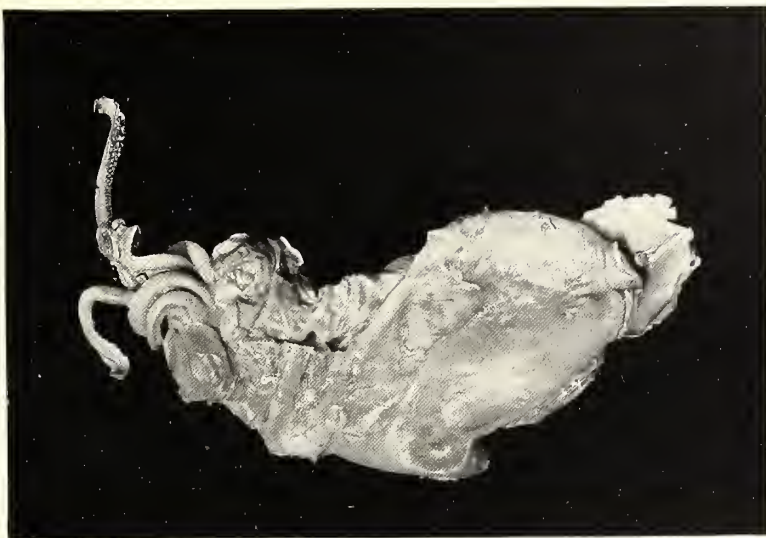




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CARCINOMA OF THE THYROID IN THE SALMONOID FISHES

An investigation and experimental study conducted jointly by the
Gratwick Laboratory of the State Institute for the Study of Malignant
Disease, Buffalo, N. Y., and the United States Bureau of Fisheries



By Harvey R. Gaylord, M. D.

Director, State Institute for the Study of Malignant Disease, Buffalo, N. Y.

AND

Millard C. Marsh

*Biologist, State Institute for the Study of Malignant Disease, formerly
Scientific Assistant, United States Bureau of Fisheries*

WITH THE COLLABORATION OF

Frederick C. Busch, M. D., *Internist*, AND Burton T. Simpson, M. D., *Pathologist*
State Institute for the Study of Malignant Disease

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CARCINOMA OF THE THYROID IN THE SALMONOID FISHES.



By HARVEY R. GAYLORD, M. D., and MILLARD C. MARSH

WITH THE COLLABORATION OF

FREDERICK C. BUSCH, M. D., and BURTON T. SIMPSON, M. D.



INTRODUCTION.

HISTORY OF THE PRESENT INVESTIGATION.

In 1907, by the natural trend of the general investigation into cancer which was being conducted by the State of New York through the medium of the Gratwick Laboratory, now a part of the State Institute for the Study of Malignant Disease, that institution became interested in the possible distribution of cancer and allied affections in fish. Through publications of Plehn and Pick the attention of cancer investigators was attracted to a disease known as carcinoma of the thyroid in the Salmonidæ. The disease had been described in the literature under various names and was known to fish culture as "gill disease," "throat tumor," etc. The work of Marianne Plehn had served to establish the nature of the disease as cancer or carcinoma of the thyroid, intimately associated with enlargement of that organ of a more simple nature which might be considered goiter.

In 1907 the director of the Gratwick Laboratory took occasion to visit one of the hatcheries in New York for the purpose of inquiring into the prevalence of this disease in the hatcheries of the State. He learned that one or two fish with tumors at the junction of the gills had been found and in the spring of 1908 a report came from this hatchery that an epidemic was in progress, and an examination made on the spot revealed the presence of visible tumors in some 700 fish. Attempts were made to study the conditions under which the disease developed in this hatchery, and observations were carried through the summer of 1908. Attention was called to the existence of the disease in two other hatcheries in the State of New York, and at the conclusion of the summer's work it became apparent that the great extent of the disease, the existence of which in other States had been reported to us, was such that a comprehensive investigation could probably be successfully accomplished only in cooperation with the United States Bureau of Fisheries.

For this reason, in February, 1909, the results obtained and the importance of the subject were laid before President Roosevelt, who decided that a joint investigation between the Gratwick Laboratory and the Bureau of Fisheries should be undertaken. The Commissioner of Fisheries, Hon. George M. Bowers, detailed Mr. Millard C. Marsh as the representative of the Bureau to cooperate with the State. Facilities were at once afforded for a detailed investigation at one of the Government fish hatcheries where the disease was endemic.

The first summer's work was carried out by Dr. Gaylord at this Government hatchery. In the winter of 1909-10 Mr. Marsh, working at the Gratwick Laboratory in Buffalo, in conjunction with Dr. Gaylord, carried out a series of experiments on feeding, crowding, vitiation of water, etc. The summer of 1910 was again spent by Dr. Gaylord and Mr. Marsh at the Government hatchery in question. The winter of 1910-11 Mr. Marsh continued the work in Buffalo. In July, 1911, Mr. Marsh was detailed for service in Alaska and Dr. Frederick C. Busch, of the State Institute for the Study of Malignant Disease, took up his part of the work. In the pathologic histologic part of the work Dr. Burton T. Simpson contributed largely, having studied many hundred sections and recorded important facts. The experimentation at the Government hatchery has been conducted to a point where it is now possible to make the first report on the studies thus far conducted into this disease.

In this report we have attempted to determine the nature of this affection, to present a well-defined picture of the disease as it occurs in hatcheries under conditions of practical fish culture, to determine as nearly as possible the factors which predispose to the development of the disease, and to present certain conclusions regarding its nature. Identification of the agent which causes this disease we have left for future investigation. How important to fish culture and how significant to cancer research future studies in the more sharply defined field to which this report is an introduction will prove, may be easily seen from the significant facts thus far adduced.

In our investigations and in the preparation of this report we have had assistance from many persons to whom we wish here to acknowledge our indebtedness. The joint investigation was begun during the incumbency of Hon. George M. Bowers as Commissioner of Fisheries, and the resources and facilities of the Bureau were freely used by him in furtherance of the mutual undertaking. Likewise, Dr. Hugh M. Smith, who as Deputy Commissioner interested himself keenly in the encouragement of the work, has since his recent appointment to the commissionership continued in every way to give indispensable support and cooperation. The members of the fish-cultural and scientific staffs of the Bureau in Washington, and superintendents and employees of stations, have given much time and effort in various ways. Of the latter, Mr. C. G. Atkins, superintendent of Craig Brook station, has been our chief dependence.

The Commissioner of Forest, Fish, and Game of the State of New York, Mr. James S. Whipple, and the State Fish Culturist, Dr. T. H. Bean, have furnished valuable assistance by placing at our disposal facilities and material at certain of the State hatcheries. The superintendents and employees at the hatcheries at Bath, Caledonia, and Cold Spring Harbor gave much direct assistance.

The excellent plates in color and most of the other drawings are the work of Miss E. S. Carrington, of Louisville, Ky.

Dr. F. W. Baeslack, formerly of the Gratwick Laboratory, autopsied a portion of the tumor-fish material. Of the present force of the laboratory the work of Mr. Damon Averill deserves special mention. He has had to do with the fish material from the beginning of the investigation, has done a part of the histological work and all the extensive photography involved; to the photomicrographs particularly, on which the value of this report largely depends, he has devoted much pains and skill.

Miss C. A. Maclay, secretary of the State Institute, has had charge of many details concerned in the investigation, has prepared much of the manuscript for the printer, and taken part in the proof reading.

The translations of the summary and conclusions into German and French we owe to the skill of Dr. Max Breuer and Dr. Charles van Bergen, both of Buffalo.

HISTORY OF THE DISEASE.

The existence of this disease was first noted in 1883 by a German investigator, R. Bonnet, who published in the Bavarian Fisheries Journal the description of a peculiar epidemic occurring among the lake trout (*Trutta lacustris*) at the fish hatchery in Torbole on the Gardasee, and, between the middle of February and the end of June, killing no less than 3,000 fish. All of these fish had tumors at the junction of the gills.

Bonnet did not recognize that this disease was cancerous in its nature. The first to recognize the tumor as carcinoma was Scott (1891). The full text of his "Note on the Occurrence of Cancer in Fish" is as follows:

The fish afflicted with this disease were all specimens of the American brook trout (*Salmo fontinalis*) kept in confinement in one of the ponds at Opoho belonging to the Dunedin Acclimatization Society. Males and females were alike affected and the diseased fish never recovered. Through the kindness of Mr. Deans, the manager, I was able to examine several specimens showing the disease in various stages of advancement, and the following is a short account of the naked-eye and microscopic appearances of the growth.

In the earliest stages the ventral wall of the pharynx in the middle line, a short distance behind the tongue, is seen to be somewhat roughened and raised in low irregular swellings. At this stage nothing is to be seen unless the mouth is opened widely. As the tumor grows, however, not only does it involve more and more of the pharyngeal floor, spreading also to a slight extent laterally, and involving the ventral ends of the gill arches, but it ultimately shows itself externally as a rounded pink lump on the isthmus in the angle between the diverging branchiostegal rays.

A microscopic section of the tumor shows all the stages in the development of a carcinomatous growth. In parts a purely glandular structure is seen—the glands, apparently, of the acinotubular type. Elsewhere, owing to the proliferation of the cells, the gland acini have become distended and irregular in form (adenoma stage), while in large areas these overdistended acini have burst, as it were, and the liberated cells, making their way into the stroma, infiltrate it, and all gland structure is lost (carcinoma stage).

Of the two figures which accompany this note, the first (Fig. 1) shows the floor of the mouth and pharynx, as seen from above, of a fish suffering from the disease. The nodular character of the tumor is clearly seen. The second shows a small portion of a section as seen under the microscope. A distended acinus is seen liberating a stream of cells into the gland stroma (Fig. 2).

The occurrence of cancer in the lower animals has been frequently noted of late years, and it is by no means so rare among them as it was at one time thought to be. I have, however, been unable to find any mention of it having been noted in fish.

A report on this disease in trout appeared in 1902 in the General Fisheries Magazine (German), by Marianne Plehn, who recognized it as a disease of the thyroid gland. L. Pick reported fully on the subject in a paper entitled "Carcinoma of the Thyroid in the Salmonidæ," describing 10 fish affected with the disease, which, in agreement with all other authorities, he concludes, is genuine cancer. He refers especially to the epidemics of the disease, descriptions of which are found below.

In the reports of the New Zealand Department of Agriculture, Division of Veterinary Science, 1901-2, is a report by Gilruth entitled "Epithelioma Affecting the Branchial Arches of Salmon and Trout." Gilruth describes a specimen, a 5-year-old salmon (*Salmo salar*) from the Clinton ponds, which had a growth on the third branchial arch and "its gill ray." It was the first specimen which had been found there. His description is as follows:

Macroscopical examination.—Growth appeared about the size of a marble, situated on the center of the third branchial arch, affecting laterally the first and third and implicating the branchiæ. The gill cleft was distended, but until forcibly opened the tumor was not visible.

Later he received three rainbow trout (*Salmo irideus*).

In each specimen the tumor was about the size of a large walnut projecting on both sides of the gill cleft. (Fig. 3.) Each tumor appeared to have started at the apex of the second branchial arch, about the base of the branchiæ, which they had implicated almost to their terminal points, only leaving a faint fringe of what were the branchiæ. The first and second arches, with their branchiæ, were also affected. The growth did not affect the apex of the arch externally, but passed on the internal surface through to both sides. The external surface of the tumor was faintly pink. On section the tumor was found to be homogeneous, pale in color, and soft in consistency.

Microscopical examination.—Fibrous capsule, covered by several layers of squamous epithelium, from which the fine fibers forming branching and anastomosing trabeculæ pass inward, inclosing more or less irregular alveoli. These alveoli are lined by an irregularly disposed layer of columnar cells, the center of each alveolus being filled with cubical cells more or less degenerated. The smaller alveoli are lined with columnar or cubical cells, and have the appearance of tubules cut transversely, the central area only containing one or two degenerated cells. Blood vessels with thin walls and wide lumina are found traversing the fibrous capsule and the fibrillar network within. Frequently hemorrhage is met with where the slender walls of the blood vessels have ruptured. In many portions of the tumor the branching fibrillæ with columnar cells on either side show an appearance recalling somewhat the fronds of the common fern. Taking into consideration the histology of the branchiæ with the above description, it would appear that the only pathological classification, at least from the mammalian standpoint, which this would come under, is epithelioma (as distinguished from carcinoma).

Gilruth gives a letter from L. F. Ayson, Chief Inspector of Fisheries, New Zealand, who states:

This gill disease was first noticed there [Masterton hatchery] among the American brook trout (*Salvelinus fontinalis*) in 1890, when three diseased fish were taken out that spawning season. The disease was peculiar to this species until the rainbow trout (*Salmo irideus*) were introduced, among which it made its appearance when they were over 3 years old. I have never found any of the brown trout (*S. fario*) affected, but took out three diseased fish from a thousand 3 and 4 year old Loch

Leven (*S. levenensis*) during the spawning season of 1896. In 1898 about 2 per cent of the American brook trout over 3 years old would be affected and about 1 per cent of the rainbow trout over that age. I have no record of ever finding any diseased fish under 3 years old.

With regard to the diseased specimens of rainbow trout which I brought to you recently, I visited the Masterton hatchery on June 16, when the manager was engaged in shifting his 3-year-old rainbow trout from their summer ponds into the spawning races, where they were sorted out, i. e., the male fish were separated from the females and the ripe female fish from the unripe; the ripe fish being stripped, and the unripe females and male fish being put into separate races. I assisted with the separating and stripping that day, when 1,200 fish were handled. From this number 29 fish affected with this gill tumor were taken out; these (with the exception of the specimens taken to your laboratory) were knocked on the head and buried.

At the Otago Acclimatization Society's Opoho and Clinton trout hatcheries the American brook trout are, I believe, the only fish affected with this disease, but at Christchurch hatchery I understand that it is common among both the American brook and rainbow trout. If it is of any interest to you I will get particulars from the Otago and Canterbury Acclimatization Societies with regard to this matter, and will also inquire whether this disease has made its appearance at the Auckland Society's hatchery at Okoroire, where only rainbow trout are kept.

Gilruth quotes Ayson further as the authority for the statement that at Masterton he was present at the handling of 3,000 or 4,000 pond-spawning fish (1902) and that, from these, 100 fish affected similarly to those described were taken out and killed; also that the manager of the Auckland Society's rainbow trout hatchery stated that 7 per cent of the mature pond fish at that hatchery were affected.

Marsh in 1903 first reported the disease in the United States as an occasional occurrence known to fish culturists, affecting yearling as well as older trout, and noted the occurrence of marked anemia in affected fish.

In the Third Annual Report of the Imperial Cancer Research Fund (English), 1908, in an article on the zoological distribution of cancer in fishes, occurs the following:

Since the first authentic case of carcinoma in a fish, viz., of the thyroid gland in a trout, was submitted to us in February, 1903, by Mr. Gilruth, over 2,000 additional cases have been reported to us from the same and other hatcheries. * * * We have been unable to approach this extremely interesting and important subject from the fact that up to the present we have been unable to find any evidence of its occurrence in the hatcheries in this country at the present time, the last epidemic of the disease appearing in 1888 in Scotland.

At a meeting of the Lyon Medicales in 1908 Jaboulay reported having had in his laboratory for study six trout affected with malignant tumors of the thyroid gland. These were sent to him in November by M. Crettiez, inspector of waters and forests of Thonon. The disease had existed at the establishment at Thonon for three years and had been first noticed by M. Crettiez in salmon hatched from eggs received from Germany. He had recently observed the disease in sea salmon, ombres-chevaliers (*Salvelinus alpinus*), and in the offspring of one hybridization formed by crossing the common female trout with the male ombres-chevaliers, to which he had given the name *Salmo thononensis*. To Crettiez the disease appeared to be clearly hereditary and at the same time contagious and always fatal, although any elaboration of his grounds for these conclusions is not given by Jaboulay. Jaboulay considers the tumor an adeno-carcinoma of the thyroid, which he says invades the thyroid region and the neighboring tissues and in its last stages generalizes in the various organs.

In the United States the disease has been known to fish culture for some 40 years, but has escaped mention, so far as we have been able to find, in the several treatises on fish culture which have been written in this country, and has not until recently been the subject of any particular study.

From time to time during the progress of this investigation we have made preliminary statements before the American Association for Cancer Research. These brief summaries are here reprinted in order to show the development of the investigation along the lines originally indicated.

AN EPIDEMIC OF CARCINOMA OF THE THYROID GLAND AMONG FISH.^a

Dr. Harvey R. Gaylord, Buffalo: This paper is a continuation of a preliminary report made before the society a year ago. It gives details of two epidemics in different parts of the country, and refers to two others. The epidemic referred to last year, which resulted in the loss of 3,500 brook trout, had, during the summer of 1909, begun to involve the brown trout and adult rainbows, so that heavy losses continued during this summer. Among the fish preserved from this epidemic was one with a tumor on the lower jaw, which on section was found to be either an implantation of the thyroid tumor or a metastasis, as the fish so affected had a primary tumor of the thyroid. From this observation it is plain that this tumor may, under given conditions, metastasize, or that it is implantable. In an epidemic in a second hatchery, an analysis of the course of the disease again showed that where fish occupied ponds which received water from ponds containing infected fish, these fish may become infected; and, furthermore, the rate at which the fish become involved increases progressively as the contents of ponds containing infected fish are added to the water which supply the fish. Another observation of importance is the discovery that lots of fish are immune. This is particularly shown in hybrid fish, in which one lot of hybrid salmon 1 year old were reduced from 1,043 in April to 44 sound fish remaining in August, whereas another lot of yearling hybrid salmon, although badly exposed by being placed in ponds into which the water from infected ponds ran, remained free from the disease throughout. Three lots of Scotch sea trout remained immune, although badly exposed. The only lot of brook trout 2 years old which were free from the disease was found on a careful analysis of their position throughout their entire life history in this hatchery, never to have been placed where the water from infected troughs or ponds flowed to them. They were placed in the uppermost pond and remained free from the disease throughout the epidemic. These observations on immunity in hybrid fish, in the light of those made by Tyzzer in inoculation of Japanese waltzing-mouse tumor, in hybrids from immune and nonimmune parents, serve to accentuate the similarity of this disease in fish to cancer in warm-blooded animals.

The disease is found to affect very small fish. A brook trout of the hatch of 1909, 3 inches in length, was shown with a tumor of considerable size from which it had died. This was the first affected fish from the hatch of 1909, and it had occupied from May until September one of five troughs which had the previous summer contained infected fish. From this it would appear that the contagion can be localized, even to given, small wooden troughs, and that these troughs can retain their infectivity from year to year. In all the epidemics thus far described, occasionally large fish, when exposed, acquire the disease. A landlocked salmon 8 years old, measuring 24 inches in length, developed large tumors, and in two other hatcheries during the past year epidemics have broken out involving considerable numbers of adult rainbow trout and large adult brook trout. Among the large fish epithelioma of the tongue or the region of the mouth is not uncommon. Carcinoma of the thyroid produces the most rapid destruction among young fish, frequently diffusely infiltrating the gills and also growing to great relative size in the small fish. The tumor erodes bone, destroys cartilage, and infiltrates the muscular structure. The tumor presents varying characteristics, frequently retaining the alveolar type with colloid, again of a strictly adenomatous type, but in all cases with areas of complete malignant degeneration and assuming the characteristics of solid soft carcinoma.

^a American Association for Cancer Research, meeting of Nov. 27, 1909, Journal American Medical Association, Jan. 15, 1910.

In the study of this interesting form of cancer, the discovery of metastasis formation, the evidences of immunity, and the influence of blood relationship to susceptibility show the practical identity of this affection to cancer in warm-blooded animals. The apparent absence of metastasis formation as a criticism was long since applied to mouse cancers and to-day falls to the ground in this affection. The evidence of infectivity and contagion appear to the observer to be conclusive, and when correlated in the evidence of infectivity in cancer in warm-blooded animals should prove the greatest support to the parasitic theory we have yet encountered. The marked evidence of infectivity and contagion found in carcinoma of the thyroid in fish appears to be an accentuation of similar evidence of a less convincing character found in other species. Its accentuation in this disease can be largely explained by the environment and the conditions under which fish are artificially propagated.

AN EPIDEMIC OF CANCER OF THE THYROID IN BROOK TROUT IN A FISH HATCHERY.^a

Dr. H. R. Gaylord, Buffalo: This is a preliminary report on the investigation of a fish hatchery in which an epidemic of carcinoma of the thyroid in 2-year-old brook and brown trout exists at the present time. In this hatchery the water supply is from a spring coming out of a hillside, which runs into a basin or pond, from which it is piped to a small reservoir and then through a series of tanks which draw their supply directly from the reservoir. Carcinoma of the thyroid was discovered in a fish in the basin on the hillside two years ago. One year ago this basin was emptied and restocked with young fish and feeding was practiced for the first time in this upper pond. Of the tanks fed from the water passing through this pond, one tank containing 3,700 brook trout 2 years old, hatched from eggs brought from a hatchery in an adjoining State where the disease is not known to exist, showed 700 fish in various stages of the disease. The outbreak occurred in the early autumn and fresh cases are continually developing. In an adjoining tank, which has no connection whatsoever with the tank in question, are 200 brown trout reared from eggs hatched on the premises. Between 3 and 4 per cent of these fish show disease. The infected fish at no time have come in direct contact with the fish in the upper pond where the disease is known to have existed; neither at any time have the brook trout and the brown trout been in contact with each other. I believe that the state of affairs found in this fish hatchery points very strongly to the infectious nature of this form of cancer and that the contagion is water-borne. It is possible that feeding liver into the waters of the fish hatchery has some relation to the outbreak in this case. I know of a second fish hatchery where the disease was endemic for a number of years and where the feeding of liver has been changed to the feeding of chopped sea fish and in the last three years the disease has disappeared. I also know of two other fish hatcheries in which the disease is endemic, and I am undertaking a systematic and careful study of a number of fish hatcheries for the purpose of further determining the conditions under which the disease occurs.

NORMAL THYROID IN SALMONOIDS.

The thyroid in fishes has given rise to a not inconsiderable literature, beginning with Simon's paper (1844) on the comparative anatomy of the gland, in which he first identified the thyroid in fishes. The detailed studies of its histology belong to a much later period. Most of the work has been upon genera outside the Salmonidæ, and especially upon the lower forms of fishes. Maurer (1886) described and illustrated the development of the thyroid in a trout, and the location of the thyroid follicles in the adult, with a semi-diagrammatic drawing of the histology of the adult follicles. In 1910 and 1911 Marine and Lenhart published photomicrographs of normal thyroid in the brook trout in illustration of studies of enlargement of the gland. Thompson in 1911 published a paper on the thyroid and parathyroid of vertebrates, with *Amiurus* as the only teleost

^a American Association for Cancer Research, meeting of Nov. 27, 1908, *Journal of American Medical Association*, Jan. 30, 1909.

representative. In 1911 Gudernatsch, in the most extended study of the fish thyroid that has yet appeared, diagramed the distribution of the follicles in 22 genera of teleosts including 4 genera and 5 species of salmonoids, and showed the minute structure in several genera including 2 species of salmonoids, viz., a Pacific salmon and the American brook trout (*Salvelinus fontinalis*). He was the first to emphasize, in a preliminary statement before the American Society for Cancer Research (Nov. 27, 1909), the lack of a capsule in the thyroid of teleosts.

It is thus seen that a number of studies having to do with normal fish thyroid have been made, and are widely scattered among the many and diverse genera of this great class. Not until recently has any particular attention been focused upon the Salmonidæ. The amount, distribution, and structure of the gland may be said to have been shown for individuals whose source and history and the conditions under which they had been living are not well known or are not stated, but which are presumptively normal and show no obvious pathologic changes. If, however, one limits the normal to the minimum of the thyroid exhibited by adults from streams far from and unaffected by civilization, where the fish are obviously living strictly in a state of nature, there is yet but a meager exposition of the normal thyroid in the salmonoids. We believe that the final comparison is to be against a norm set up by such individuals, and that most trout from aquariums, markets, fish-cultural establishments, and from artificially stocked streams and lakes or unstocked streams or lakes close to civilization or much frequented by people, have either abnormal thyroids or are not to be judged by criteria obtained from strictly wild trout.

In our specimens of wild brook trout we are unable to find the thyroid distributed as widely and in such quantity as shown by Gudernatsch (1911, a, p. 753 and pl. II) for this species. He finds it extending into the gill arches, infiltrating muscle bundles and in places completely filling the available thyroid spaces. We find these conditions in domesticated fish, but not in our wild specimens. His material was in part obtained from aquarium fish, and in such we would expect such a distribution. It may even occur in specimens from some streams or lakes. We would infer that all fish exhibiting it may be presumed to have been under influences foreign to those usually obtaining in strictly wild natural conditions, but they may perhaps be considered to represent a normal for trout under a modified régime without presumption of any definite pathologic change. The minimum quantity of thyroid and its more restricted distribution appear to us as affording a more representative picture of the ultimate normal. Maurer, while not mapping in detail the distribution in the adult, describes a condition which speaks for the more confined arrangement of thyroid tissue (fig. 5 and 6).

EMBRYOLOGY.

Maurer (1886) has described the development of the thyroid in trout. According to his observations, about the twenty-seventh day after fertilization, the embryo being 6 millimeters long, an unpaired median evagination arises from the ventral epithelium of the pharynx (fig. 7). This is the earliest differentiation of thyroid. It lies in front of the heart in the bifurcation of the heart tube into the hyoid arteries, and consists

of several layers of cubical cells. At this time no cartilage is differentiated, but the hyoid arch is well developed and the true gill arches are indicated, the brain vesicles and mouth opening are present, while the only macroscopic vessels of the region are the S-shaped heart tube and the two hyoid arteries.

The primary evagination lies close but not attached to the arterial wall, from which it is separated by connective tissue. At 32 days it has become spherical, has a lumen of its own, its epithelium is single layered and is connected with the mother cells only by a slender pedicle. (Fig. 8.) At 35 days it has completely separated (fig. 9), is about 0.04 millimeter in diameter, and lies exactly in the fork of the heart tube, which is 0.1 millimeter in diameter before the bifurcation. The four pairs of true gill arteries are now visible.

During the next six days the vesicle becomes somewhat elongated and changes its position. It now measures about 0.03 by 0.06 millimeter and has been pressed back of the bifurcation and lies ventral to the gill artery trunk, or ventral aorta (fig. 10). Colloid is now present and the vesicle begins to put out buds which rapidly develop a lumen filled with colloid and quickly separate. These multiplying buds grow around the aorta to the dorsal side and keep pace with its increase in length until, at 77 days or 3 weeks after hatching, that portion of the aortic trunk from the last branchial arteries forward to the bifurcation is surrounded by thyroid follicles. Finally, thyroid growth failing to keep pace with the lengthening of the ventral aorta, the adult condition is approached when the thyroid mass breaks up into irregular deposits or clusters of follicles which remain in the vicinity of the ventral aorta.

In the adult trout the greater portion of the thyroid is dorsal to the aorta. Maurer's description therefore requires that it migrate, from its origin dorsal to the heart tube, to the ventral side of the aorta and then back again to the dorsal side, and this view is confirmed by our specimens.

While colloid no doubt appears very early in the embryo and before the latter leaves the eggshell, Maurer's statement that it appears about the forty-first day of incubation is indefinite, since incubation proceeds over a considerable range of temperature and is much more rapid in the warmer water. The stage of incubation may be accurately stated in temperature units when both time and temperature are known. From the facts at hand, however, it may be expected that all normal trout embryos have developed colloid as soon as the hatching stage is reached.

In our specimens of hatchery brook trout still in the sac stage, but some days hatched, colloid is plainly visible (fig. 13) in many follicles. The amount and location of thyroid tissue is even at this early stage subject to considerable variation. The follicles are, however, always relatively few. In three examples the total number of distinct follicles recognizable by serial sections throughout the floor of the mouth was 24, 27, and 33, respectively. In other cases there appears to be a smaller number. In distribution two more or less distinct deposits are recognizable, besides scattered follicles. One of these is at or in front of the level of the epithelial invagination which is to become the jugular pit, a region which will be shown later to be the seat of thyroid deposits in the adult. At this stage it is already a very definite infolding. The follicles

are here in close relation to and not infrequently lie in actual contact with (fig. 10) the cells of this invagination, and thus illustrate the probable origin of pit tumors. One or more of the thyroid follicles can be easily dragged away from their neighbors with the growth of the pit region and come to lie immediately beneath the pit epithelium, as has been remarked in the discussion of distribution (fig. 14). When the thyroid later proliferates abnormally, an independent tumor begins to occupy the jugular pit.

In the adult scarcely any thyroid is located so far forward as in these recently hatched fry, where in the neighborhood of the pit it is to be found cephalad of the first arch and of the bifurcation of the aorta. The other deposit or aggregation of follicles centers in the region occupied by the adult thyroid, or in the vicinity of the second arch. They are not arranged with any regularity, were not observed in any case to extend laterally upon the gill arches but scatter along directly beneath the mesal bridge, and reach in a few cases as far back as the beginning of the fourth arch. Between the follicles about the jugular pit and those in the vicinity of the second arch, a gap usually intervenes in which no thyroid occurs. The limits of variation in amount and position of thyroid tissue can not be defined here, but from the material examined it appears that either of the chief groups of follicles as just described may in some specimens be entirely wanting, and that the adult gland may develop from one of these groups alone.

GROSS ANATOMY AND DISTRIBUTION IN THE ADULT BROOK TROUT.

While the thyroid is not a definite gland unit and on account of its small size, separation into discrete aggregates, and lack of encapsulation can not be extirpated, or dissected free in its entirety, it is nevertheless macroscopic in adult trout. On median section of the floor of the mouth, delicate small masses of tissue may be seen about the ventral aorta near the first and second arches between the vessel and the cartilages and bone of the mesal bridge into which the gill arches unite. These masses contain the chief aggregates of thyroid follicles, and consist in large part of connective tissue. They are likely to be found close to the second gill arch, and more likely to lie opposite the interspaces between the arches than opposite the arch itself. Under a hand or dissecting lens the individual follicles may be recognized embedded in the mass. Only the massed follicles are to be seen with the naked eye and therefore the outlying small deposits are not demonstrable save on microscopic section. The macroscopic thyroid masses in wild fish will only be found close to the middle line and at or just in front of or behind the second arch. Such masses closely resemble in appearance the fatty and areolar tissues which contain no thyroid, and can not be recognized with certainty as thyroid without a lens.

The exact location of thyroid follicles in the adult is variable. Perhaps every fish gives a recognizably distinct distribution pattern. To understand the location of the thyroid some consideration of the anatomy of the skeletal and other parts of the floor of the mouth is necessary. There are five pairs of branchial arches, of which only the cephalic four bear gills. Each arch save the fifth is composed of several bones, of which the ventral, or hypobranchial, is united with its fellow of the opposite side by the mesal unpaired basibranchial, and by cartilaginous copulæ which thus form the links

between the right and left halves of each pair of arches. The basibranchials are connected with each other by these same cartilaginous copulæ, so that a solid mesal bridge is formed on the floor of the mouth, continuous with the tongue and reaching back to the fourth arch. The basibranchials lie opposite the interspaces between the arches, while the copulæ lie opposite the arches themselves. The first and second basibranchials are well ossified, the third less so, and the fourth is mostly cartilage.

Immediately beneath this bridge runs the ventral aorta. The bulbous aorta is located deeper, well beneath the floor of the mouth and somewhat back of the fourth arch. From it the ventral aorta runs dorsocephalad to a point just under the third arch. Here are given off the two trunks which soon bifurcate into the third and fourth branchial arteries supplying the corresponding gills. Thence the ventral aorta runs cephalad and slightly ventrad. Near the caudal margin of the second arch the second pair of branchial arteries is given off, supplying the second pair of gill arches. Finally the ventral aorta, just as it reaches the first arch, bifurcates into the first pair of branchial arteries. A certain amount of space is left about the ventral aorta between it and the parts which inclose it. This space is greater dorsal to the vessel, and especially at the origins of the first and second pairs of branchial arteries. It contains the normal thyroid and its supporting tissues.

Figures 15 and 16 illustrate the lateral, longitudinal, and dorsoventral distribution of normal thyroid. They represent the condition in no single fish, but show compositely a probable average from a number of individuals. Two chief masses of thyroid may usually be recognized, the follicles clustering at and back of the first and second pair of branchial arteries, with usually a definite space between them in which but few and scattered follicles occur. Occasionally three masses or groups are recognizable, and the masses themselves present irregularities in the arrangement and number of follicles. Exact medisections show less thyroid than those slightly sagittal on account of the extension of the copulæ and basibranchials to the aorta at the second and third arches on the mesal line.

We have not found in the normal wild fish studied by us any lateral extension of thyroid structure along the branchial arches. Most of it, in fact, hardly reaches the lateral margins of the mesal bridge. The most cephalic extensions rarely reach the first basibranchial, and on the mesal line scarcely to the first copula. The extreme caudal extension is to the fourth arch, but usually there are but few follicles either at or behind the third pair of branchial arteries. Follicles are present in bone spaces, but in normal wild trout we have never found them among the muscle bundles. They are frequently embedded in the fatty tissue network or lie loosely attached to the vessels or other tissues, but never show any invasive tendency, nor do the follicles occupy more than a part of the apparently available space of the thyroid region.

ANOMALOUS DEPOSITS OF THYROID.

In a quantitative sense all the thyroid of importance is confined to the immediate vicinity of a portion of the ventral aorta. As the thyroid is a somewhat diffuse organ

one might expect to find instances of remotely placed deposits. We are therefore surprised to find the sharp delimitation to the region already described which appears to exist in our wild specimens, with one marked exception, i. e., the jugular pit to which reference has already been made. It has been assumed by some writers that aberrant thyroid deposits in some regions might be frequently expected. This has been due to the development of tumor nodules in regions beyond the normal and usual seat of distribution, such as the lower mouth parts and gill arch region. The only outlying tumors of this sort which may be inferred with certainty to arise from original deposits of thyroid are the so-called pit tumors.

In the adult trout there occurs on the ventral side of the head between the dentary bones a median irregular depression or blind pit open to the exterior. It is the region where the muscles between the dentaries and those of the branchiostegals become common. The skin dips into its ramifications with many plications and infoldings. It is an entirely superficial and exterior landmark, and though independent of and well removed from the thyroid region in the adult, is of some importance in thyroid pathology, since at an early stage it is in closely apposed relation to the thyroid region, and is the occasional seat of detached thyroid follicles and of independent thyroid tumors. This much branched and partitioned cavity may be designated as the jugular pit (fig. 11). It may be recognized at or soon after the hatching of the embryo. Normal thyroid has been several times observed immediately beneath the pit epithelium in wild brook trout (fig. 14), where its presence may be readily explained by the mechanics of development of the parts (fig. 12). Since of 91 trout with tumors, 25 showed pit tumors, one may conclude that more than one-quarter of all brook trout have normally some thyroid follicles in the region of the pit.

Occasionally detached tumors develop in the gill arches. We have never actually seen thyroid follicles on the free portions of the gill arches, and there is little embryological presumption in favor of such deposits, notwithstanding the relation of the gill arches with the thyroid region. The tip of the lower jaw has even much less anatomical relation to the thyroid region, rendering it an unlikely place for stray follicles. The examination by serial sections of the tips of the lower jaws of about 25 trout failed to show any thyroid here. The region is called into question as a seat of normal thyroid deposit on account of the rare cases of a thyroid tumor occupying this site. The actually observed occurrence of normal thyroid in the pit and the incidence of tumors here make it extremely probable that no other extralimital deposits occur with any frequency, else such would declare themselves in tumor formation.

HISTOLOGY.

A closed alveolus is the unit of the thyroid gland. These alveoli are apparently independent of each other save as they are more or less bound together by the vascular framework and connective tissue stroma. Their lumina have no connections with each other and each alveolus independently discharges its secretion into the circulation. Many alveoli are quite isolated from their kind and lie loosely in the tissue, whether connective, muscle, bone, cartilage, or fat. In the simplest adult condition (fig. 14-21)

they are typically spherical, subspherical, or slightly elongated, and consist of a single layer of flattened epithelium, with a large lumen completely filled with homogeneous colloid readily stainable by cytoplasmic stains. The cells of this epithelium are polyhedral, very flat, with very deeply staining slightly vesicular nuclei, lying parallel with the longer dimensions of the cell. The nucleus is longer than wide, about as thick as the short diameter of the cell, but its other dimensions are shorter than those of the cell. In size, alveoli show wide variation, the smallest measuring as little as 0.02 millimeter, or even less, in diameter. From these all sizes are to be found up to plainly macroscopic follicles at least 0.75 millimeter across. Perhaps even larger ones occur. Most of the alveoli of course fall well within these extremes. Only the largest are visible to the naked eye.

There is thus a promptly recognizable similarity between the structure and appearance of the thyroid unit in the trout and that of man and other mammals. The entire gland in these groups is similarly comparable in location, function, and perhaps in size, though it is impossible to weigh the trout thyroid and difficult to estimate its weight or bulk. The chief difference between the gland in fish and mammals lies in the absence from the fish thyroid of even a suggestion of a capsule, which in man is a definite and important structure which completely delimits the thyroid from the neighboring tissues and confines its units as a definite gland organ. The trout thyroid lies in the various tissues beneath the floor of the mouth without any very definite interstitial tissue of its own.

For the normal structure of the thyroid we have examined trout taken from natural waters of the country, such as streams and lakes in wild and unsettled regions. From these it is apparent that there is no inconsiderable variation in the thyroids of adult fish in their natural habitat. This variation certainly depends largely upon age and season, is no doubt in part individual, and is in our opinion also a function of other causes among which is the nature of the waters inhabited, whether shallow, rapidly flowing streams or the more quiet and deeper lakes. These natural conditions react with the metabolism of the fish.

The simplest condition of the thyroid, as described above, was seen in wild brook trout taken in January from the Au Sable River in Michigan. (Fig. 17.) The same species taken in June from streams in Wisconsin differ in showing somewhat higher epithelium, which may be regarded as cuboidal. Our specimens from these two sources show the simplest or lowest epithelium, in most cases flattened and never higher than cuboidal. Specimens taken in May from a lake in Algonquin National Park, Ontario, Canada, show a further advance. The epithelium is distinctly higher and the general character of the thyroid picture seems to us to separate these fish from the other groups of wild fish discussed above and to justify their consideration under the heading of simple hyperplasia.

SIMPLE HYPERPLASIA AND COLLOID GOITER IN WILD AND DOMESTICATED FISH.

The picture of the normal thyroid in the wild Salmonidæ is extremely characteristic, and although, as described, considerable variations are found in the size of the alveoli,

there is but a very limited range of change in the epithelial cells. So characteristic is this picture that it is possible to recognize the condition of simple hyperplasia of the thyroid, although the exact relation of simple hyperplasia to the function of the organ is not clear. We have encountered a condition of the thyroid in specimens of brook trout taken from the Algonquin National Park in Ontario, Canada, where the change is sufficiently marked to constitute, in our opinion, a condition of simple hyperplasia in fish living under wild conditions. (Fig. 18.) The specimens were taken in the regular course of angling on several days in Little Island Lake in the park. The picture presented by the thyroid of these fish is sufficiently characteristic to permit the description of the thyroid of any one specimen to serve for the rest. As compared with the thyroid structure of Wisconsin and Michigan wild brook trout, the alveoli lie more closely packed and present much more the appearance of a definite organ than in the strictly normal condition. The alveoli are of much more irregular shape, presenting irregular forms and protrusions, smaller pouch-like additions to the typical spherical or oval alveolar structure, and evidences of budding. The epithelium is high cuboidal, stains more deeply, and the long axis of the deeply stained nucleus is usually perpendicular to the circumference of the alveolus. The colloid is diminished in amount, many of the smaller alveoli containing little or none. It stains less deeply than in the normal structure. There are evidences of hyperæmia in the stroma and the stroma is much richer in small cells than in the normal. The total number of alveoli seems to be increased. We have not seen any evidences of karyokinetic figures in the cells. The epithelium never reaches the high columnar and bizarre shapes found in the early stages of carcinoma. The entire thyroid structure is more uniform in type.

Simple hyperplasia of the thyroid has been described by Marine and Lenhart (1910) as occurring in fish obtained from Lake Erie. Pike and bass, according to these authors, are commonly affected; sheepshead and herring more rarely. They also report an example of spontaneous colloid goiter in the pike which they consider the terminal stage of hyperplasia that has undergone resolution.

A simple hyperplasia of this type undoubtedly occurs in fish under domestication. It is impossible to distinguish simple hyperplasia in fish hatcheries from the first stages of carcinoma of the thyroid, a difficulty which is common to the diagnosis of all malignant tumors. We have been fortunate in having for study at Craig Brook a variety of the Salmonidæ which possesses natural immunity to carcinoma of the thyroid. These fish are the Scotch sea trout (*Salmo trutta* Linnæus). The original stock was obtained from abroad as eggs, hatched in the hatchery, carried through its various troughs, and the adult fish ultimately came to occupy the ponds lying in a position where they received the water from ponds above, in which carcinoma of the thyroid in brook trout was extremely prevalent. The facts bearing on the evidences of immunity in this connection will be considered later. The eggs taken from these domesticated sea trout have been again hatched in the hatchery, maintained in the outside smaller troughs, and we have thus had an opportunity to study the offspring of the adult fish at various stages, as well as the condition of the thyroid in the larger fish. We have never found macroscopic evidence of even the earliest stages of carcinoma of the thyroid in the younger of these

fish. The examination of specimens of the offspring of the older fish at the fingerling stage reveals the thyroid of occasional specimens in a state of simple hyperplasia (fig. 20), perhaps slightly more marked than that found in the wild fish from Algonquin Park. (P. 75.)

In these small fish the thyroid is not markedly increased in amount and is largely localized about the great vessels, but occasional groups of alveoli are found somewhat more widely removed from these structures than normal, and occasional small groups in the infoldings of the cartilage or bone or between the muscle bundles. The alveoli are not unusually large, the epithelium is high cuboidal and low columnar, the long axes of the nuclei perpendicular to the circumference of the alveoli. Both protoplasm and nucleus stain more deeply than normal. The colloid is diminished in amount and stains less well than in the normal specimens. (See fig. 20, which may be compared with a similar photograph at the same magnification of a Scotch sea trout from the same lot, 2050 A, fig. 19, in which the thyroid structure presents a characteristic normal appearance, and both may be compared with a fish of similar size taken in the wild state from the Au Sable River, Mich., fish 199 A, fig. 19, of which an illustration at similar magnification is provided.) The thyroid gland of the adult Scotch sea trout, when viewed in the light of the conditions found in the smaller fish, in which occasional examples show simple hyperplasia and the larger proportion strictly normal thyroid tissue, reveals a similar division in character of the thyroid in the adults. A larger proportion of the adult Scotch sea trout presents strictly normal thyroid tissue. (Fig. 21.) There does not appear to be an increased amount of thyroid for the size and age of these fish. The minority of the fish, however, presents microscopically a condition of the thyroid which may be spoken of as colloid goiter. (Fig. 22.) In them the alveoli are greatly increased in size, the total amount of thyroid is also increased, the walls of the alveoli are very thin, the epithelium pressed very flat, and the lumina compactly filled out with large masses of colloid.

From a careful study of the Scotch sea trout, it is clear that although, as will be shown later, they are almost perfectly immune to carcinoma of the thyroid, a certain proportion of them are affected by a process of simple hyperplasia which terminates by resolution in colloid goiter. It will be shown later that spontaneous recovery of carcinoma of the thyroid in the Salmonidæ produces an entirely different terminal picture from that of colloid goiter. In the instance above described of the Scotch sea trout, the transformation of hyperplasia into colloid goiter has been brought about by a process which has been termed resolution. In carcinoma the disappearance of the tumors in spontaneous recovery is brought about by a process of regression, a part of which may be referred to as resolution; that is, the epithelium undergoes changes of type, colloid reappears, but the bulk of the tumor literally retrogrades. Many of the alveoli totally disappear and large areas are frequently removed so rapidly as to require extensive repair by connective tissue. All of the characteristic appearances found in regression of malignant mammalian tumors, such as the frequency of large areas of hemorrhage followed by repair, the formation of pseudogiant cells by coalescence of the epithelium, great increase in the connective tissue stroma especially at the margins of

the tumor, deposition of pigment and final clearing up of these phenomena with total disappearance of the tumor, leaving only a small residue of approximately normal functioning thyroid alveoli, presents a picture which can be readily distinguished from the characteristic appearance of colloid goiter, as found in the Scotch sea trout. From the evidences obtained from the fish from the Algonquin National Park, we are of the opinion that trout in the wild state may also suffer from simple hyperplasia of the thyroid, which also, no doubt, would terminate by resolution in colloid goiter, although we have not been fortunate enough to secure such specimens from the wild state. As the majority of the Scotch sea trout under the conditions we have studied present both in the small fish and in the adults a preponderance of strictly normal thyroids, it is obvious that this condition is not the direct result of domestication, the existence of simple hyperplasia in wild fish making this deduction obvious.

Whether simple hyperplasia leading to colloid goiter in the Scotch sea trout is a process with distinctive etiology, possibly the result of unusual physiological demand upon the organ, or a greatly modified type of carcinoma of the thyroid occurring in an immune species, can not at present be determined. The observation in one or two of the older fish of red floors, and one or two reported tumors which we did not see, may indicate that further material may be secured which will throw light upon this question. For the present we would recognize a simple hyperplasia not associated etiologically with carcinoma of the thyroid.

PATHOLOGIC ANATOMY.

GROSS ANATOMY.

EARLIEST MACROSCOPIC EVIDENCE.

The first evidence of thyroid proliferation visible to the unaided eye is the so-called red floor (fig. 23 and 23a). It is a faint reddening or flushing of the median area of the floor of the mouth usually opposite to or in the neighborhood of the second gill arches. It is caused by the increasing blood supply of the main thyroid deposit and by hyperemia of adjacent tissues, which show through the epithelium. Its first appearance is sometimes a mere streak, more often a circular or irregular diffuse reddening. It usually soon spreads more widely, reaching a little out on the arches and tending to spread forward toward the first pair of arches, and is, of course, variable. At the angles between the arches the color is often heightened and very distinct. The color picture illustrating the red floor shows a well developed process scarcely prior to visible swelling, and not the very earliest flush of hyperplasia. The color changes rapidly under examination on account of the excitement of the fish due to removal from water and the vigorous handling necessary. The red flush pales rapidly under these conditions and often almost disappears in less than a minute, due to the inhibition of the circulation from nervous shock, the area taking on a dirty gray color.

The red-floor stage is not sharply demarcated from the succeeding stages. It proceeds gradually and is succeeded by or merged with visible tumor formation, the color persisting and spreading in various degrees over the subsequent swelling.

Fish which are without any clinical evidence of thyroid disease, either in externally visible swelling or the inflamed and flushed condition of the floor of the mouth, are for brevity referred to in this report as clean or clinically clean.

It is the increased vascularity associated with increased thyroid that causes the red floor, and an increased amount of hyperemic thyroid tissue of normal type sometimes makes a visible flush on the floor of the mouth so that the red floor is not an absolute and infallible sign of thyroid hyperplasia. The wild brook trout held in confinement in cement tanks and fed natural food showed after two years a number of cases of red floors. (See table VIII.) Microscopically the thyroid was considerably increased in amount but not otherwise definitely changed from the normal type. Likewise the adult Scotch sea trout show occasional red floors referable to the microscopical condition of colloid goiter. Such cases of red floors are evidently to be separated from those in which the flush is caused by the early stage of carcinoma.

VISIBLE TUMORS.

Branchial junction.—Whereas evidence of beginning growth of thyroid tissue in the affected fish is first shown by a more or less distinct reddening of the floor of the mouth, the growth of tumor tissue in the spaces about the aorta and in the muscular structure of the isthmus may proceed to a very considerable extent before the growth gives other macroscopic evidence of its presence. The illustrations of visible tumors in the literature usually depict growths appearing at the branchial junction. Because of the resistance offered to the growth of the tumor by the bony and cartilaginous structures forming the floor of the mouth, it is natural to expect that the region at the junction of the first pairs of gills with the isthmus, representing the line of least resistance, would be the first and most frequent site of the visible outgrowths. This median region we refer to as the branchial junction.

In an analysis of 91 tumors carefully classified (table I), we find that the branchial junction alone is the site of the visible tumors in but 4 cases, but where the growth of tumor tissue is sufficiently extended to protrude in other directions it is found to be the site of visible outgrowths in combination with one or the other, in 67 cases. The branchial junction is therefore one of the most common sites for the early evidence of tumor growth. In many cases the first macroscopic evidence of the disease is found in the appearance of small protrusions with smooth surface, of rose color, often not larger than a grain of rice or smaller, on each side of the isthmus exactly at the branchial junction. This evidence of tumor formation is almost always associated with the evidences of reddening of the floor of the mouth and means that the available space below the branchial arches and about the aorta is filled with tumor mass and that the conditions favoring the growth downward of the tumor have determined its first protrusion in this direction. Tumors making their first appearance at the branchial junction on one or either side of the isthmus may rapidly develop into large growths in this region. As they increase in size they become more readily recognizable, push the gill covers apart and ultimately present themselves as obvious growths protruding into the gill spaces on either side.

In the diagrams of the 48 analyzed tumors here presented, great irregularity of outline, size and form of these outgrowths on the inferior aspect of the fish may be easily studied. The freedom afforded by the spaces between the gill covers and the isthmus permits of the growths of tumors of enormous size. Figure 27 represents a 2-year-old brook trout with a tumor of such magnitude that practically the entire gill space is filled by one tumor mass, which has pushed the isthmus downward and practically occludes the entire gill space. In some cases tumors of great size may develop in such a way as to push the isthmus to one side and present the appearance of a unilateral tumor. In all these cases, however, the tumor tissue is found to extend from the median region about the aorta, which is the site of the normal thyroid tissue from which all these tumors spring. Occasionally tumors extend downward and make their first appearance through the substance of the isthmus, indicating the exquisite infiltrative character of the growth, and in one instance, the first macroscopic evidence of tumor (fig. 4) was found at the base of the isthmus in the solid muscular structure of the breast of the fish.

Floor of the mouth.—Although the lines of least resistance for the growth of tumor tissue springing from the thyroid region are obviously downward, a large proportion of all tumors give evidence of their existence in the floor of the mouth. In an analysis of 91 fish taken at random, visible evidence of tumor growth in the floor of the mouth was found in 70 instances. The reddening of the floor of the mouth, which is the first evidence of tumor growth, is replaced by infiltration through the structures of the floor of the mouth, developing either by uniform bulging upward of the floor or the protrusions of masses between the branchial junctions; or one or more rounded masses of large dimension may become prominent. (Fig. 26 and 29.) Not infrequently, besides the upheaval of the floor, the tumor tissue breaks through the elastic structure of the underlying mucosa and produces minute papillary growths. These are usually of shiny appearance, small or rounded, irregularly shaped, and present the appearance of vegetations scattered over the floor of the mouth. (Fig. 30.)

Pit tumors.—Early in our investigations Marsh called attention to the fact that the jugular pit often contained a tumor which was entirely independent of the thyroid enlargement originating in the thyroid region. (Fig. 24.) Of the 91 tumors analyzed, in 5 the only macroscopic evidence of tumor growth was in the jugular pit. In combination with other regions the jugular pit was the site of tumor growth in 20 other examples, and in the entire 91 it was the site of tumor growth in 25. As has been shown in the chapter on embryology, we were able to demonstrate the existence of deposits of normal thyroid tissue in the immediate vicinity of this so-called jugular pit. The frequency of tumors in this region strongly indicates that deposits of thyroid in this region are not uncommon, and in determining the limitation of distribution of the thyroid in normal fish, the frequency of displacement of occasional follicles in this region must be recognized. As will be seen from the diagrams, the jugular pit may be the site of outgrowth of tumor tissue of very considerable extent, and of various forms. They are usually subspherical, or hemispherical, may be slightly flattened or considerably elongated, and occasionally vegetate irregularly and take on bizarre forms. They vary greatly in size, from bare visibility to masses having a diameter of 17 millimeters or even more.

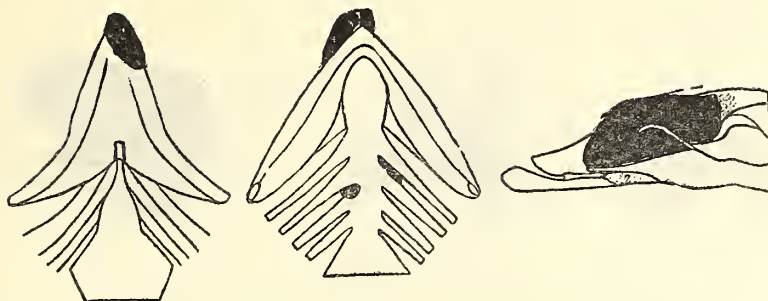


DIAGRAM 1.—Fish 61, *S. fontinalis*, length 20 cm.; type alveolar.

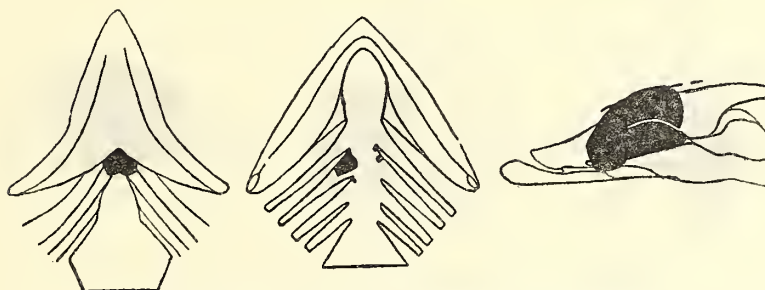


DIAGRAM 2.—Fish 72, *S. fontinalis*, length 26.5 cm.; type alveolar.

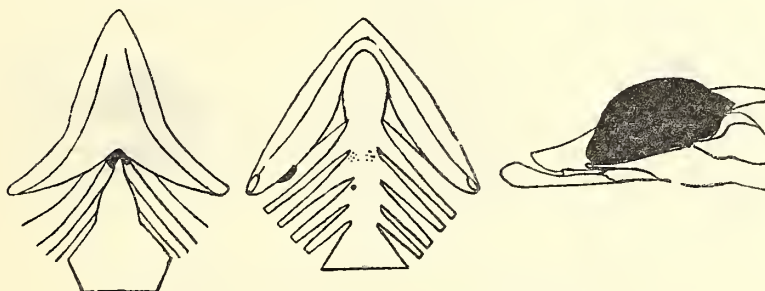


DIAGRAM 3.—Fish 73, *S. fontinalis*, length 22 cm.; type alveolar.

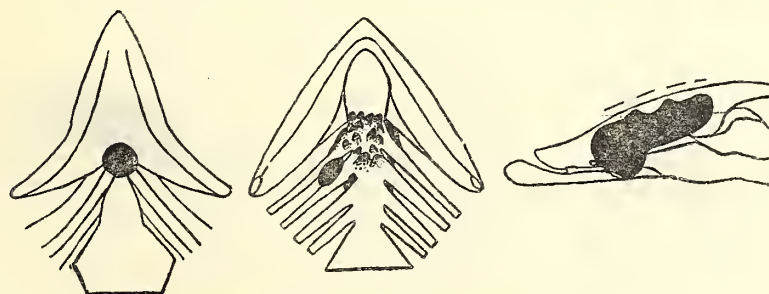


DIAGRAM 4.—Fish 75-157, *S. fontinalis*, length 26.4 cm.; type tubular.

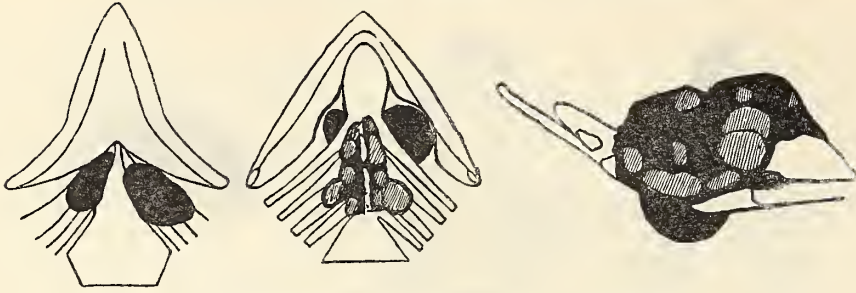


DIAGRAM 5.—Fish 92, rainbow, length 28.5 cm.; type papillar.

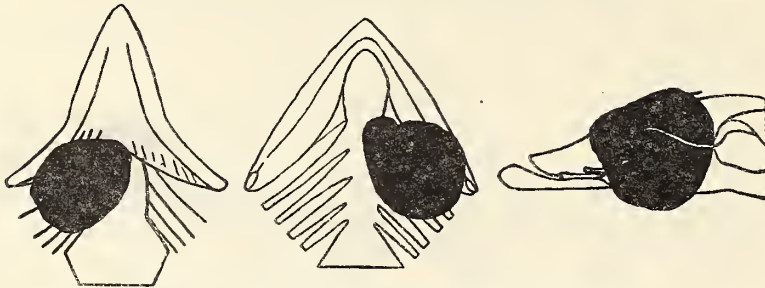


DIAGRAM 6.—Fish 93, rainbow, length 29 cm.; type alveolar.

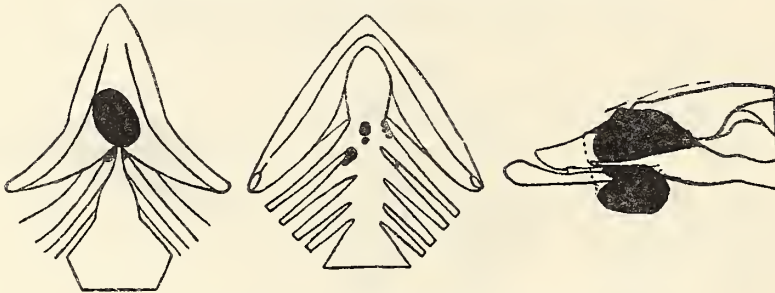


DIAGRAM 7.—Fish 94, rainbow, length 33 cm.; type papillar.

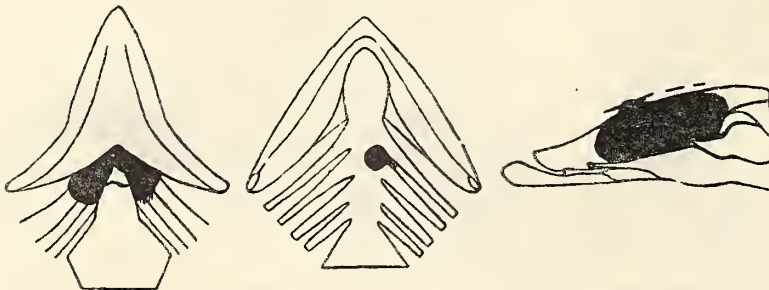


DIAGRAM 8.—Fish 96, *S. fontinalis*, length 25.3 cm.; type alveolar.

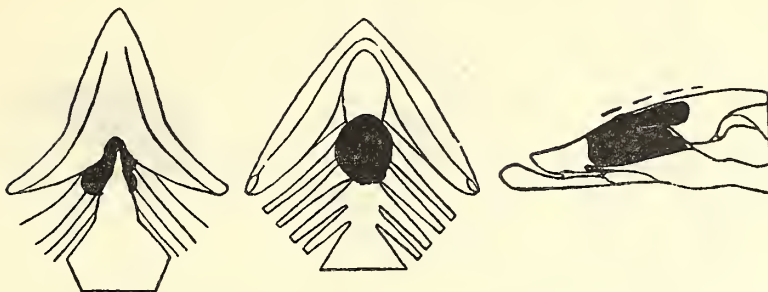


DIAGRAM 9.—Fish 106, *S. irideus*, length 25.5; type alveolar.

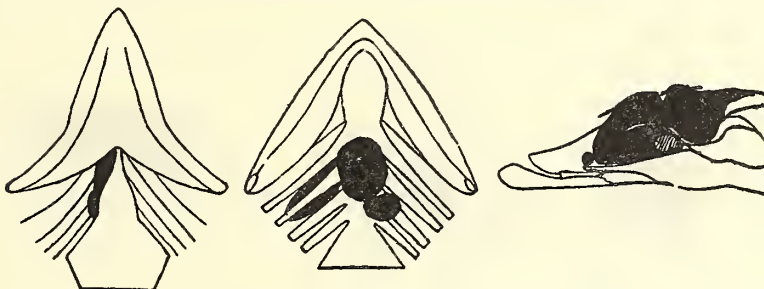


DIAGRAM 10.—Fish 107, *S. irideus*, length 24 cm.; type alveolar.

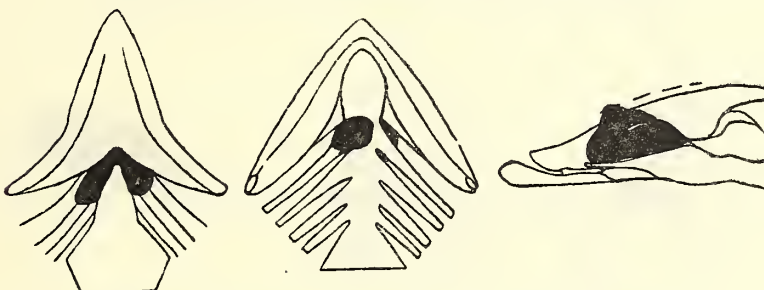


DIAGRAM 11.—Fish 108, *S. irideus*, length 24 cm.; type alveolar.

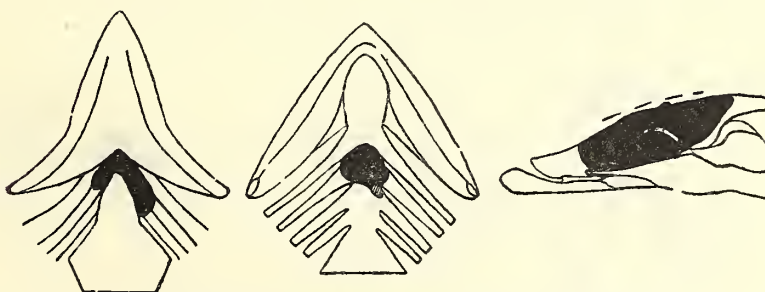


DIAGRAM 12.—Fish 116, *S. salar sebago*, length 10.2 cm.; type papillar.

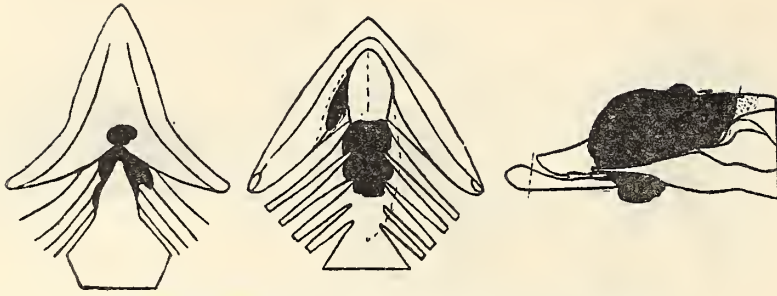


DIAGRAM 13.—Fish 120, *S. salar sebago*, length 14.7 cm.; type alveolar.

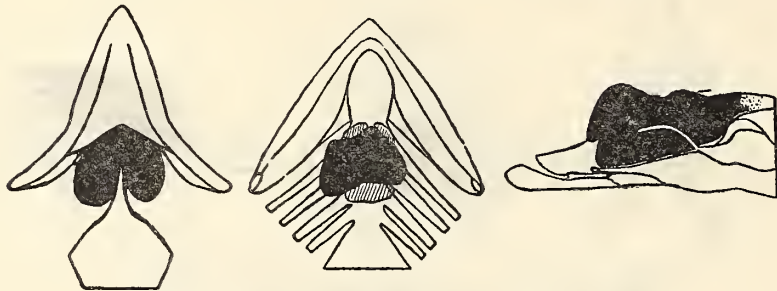


DIAGRAM 14.—Fish 124, humpback, length 14.7 cm.; type alveolar.

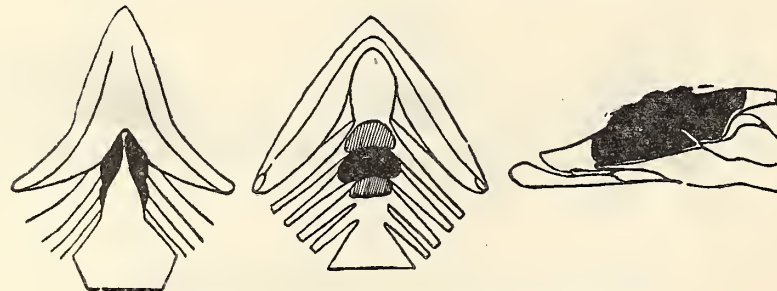


DIAGRAM 15.—Fish 125, humpback, length 14.8 cm.; type alveolar.

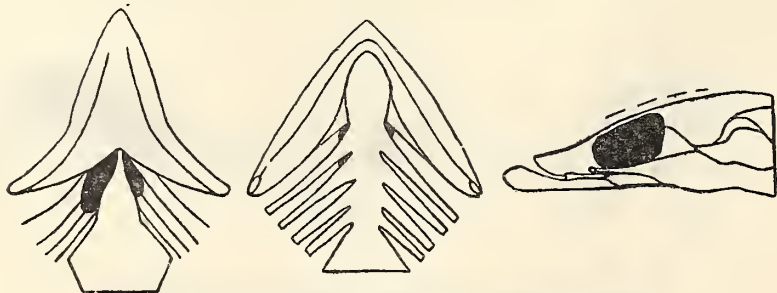


DIAGRAM 16.—Fish 131, *Coregonus*, length 60 cm.; type solid.

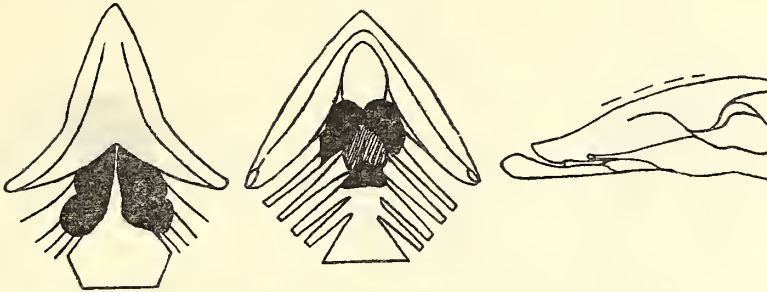


DIAGRAM 17.—Fish 133, humpback, length 14.4 cm.; type alveolar.

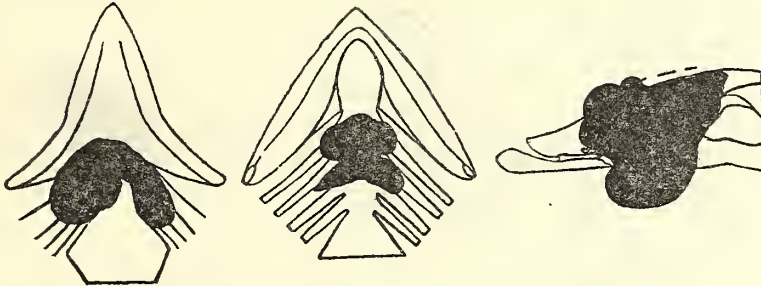


DIAGRAM 18.—Fish 139, *Salmo* hybrid, length 10.7 cm.; type alveolar.

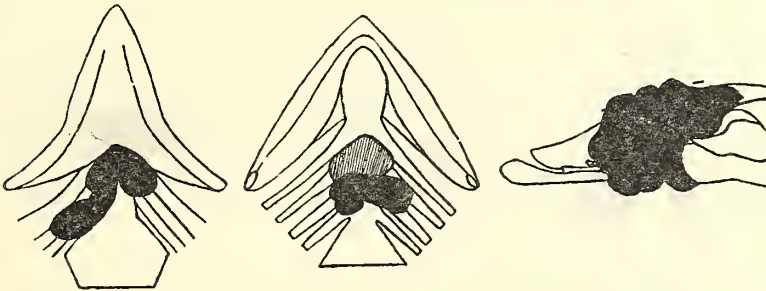


DIAGRAM 19.—Fish 140, *Salmo* hybrid, length 8.7 cm.; type solid.

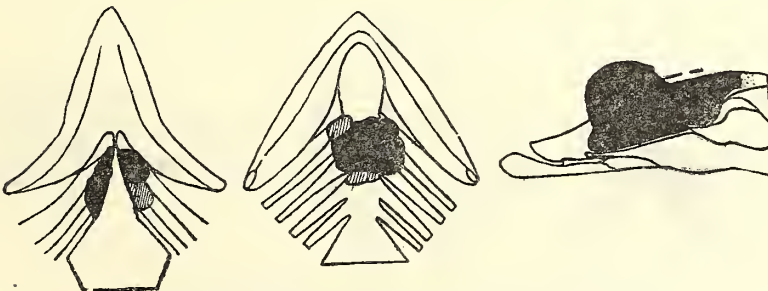


DIAGRAM 20.—Fish 151, *S. fontinalis*, length 22 cm.; type tubular.

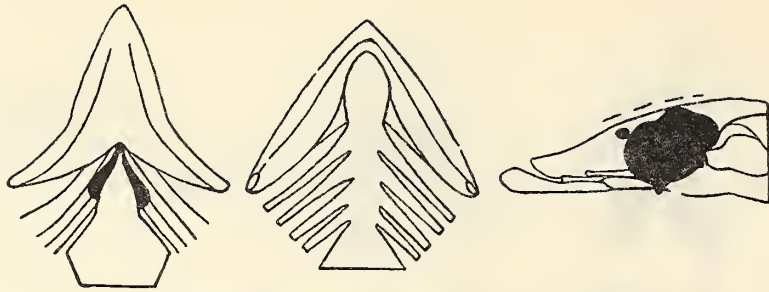


DIAGRAM 21.—Fish 152, *S. fontinalis*, length 19 cm.; type tubular.

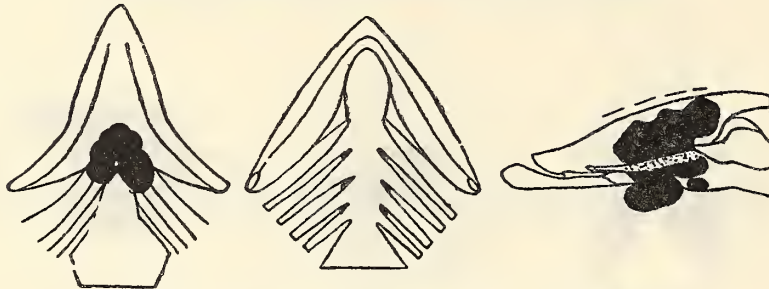


DIAGRAM 22.—Fish 156, *S. fontinalis*, length 18 cm.; type tubular.

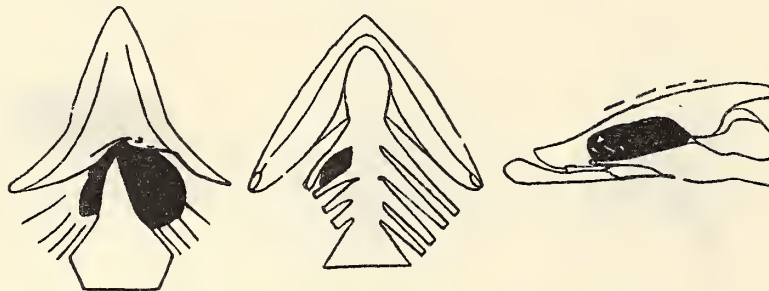


DIAGRAM 23.—Fish 172, *S. fontinalis*, length 17 cm.; type solid.

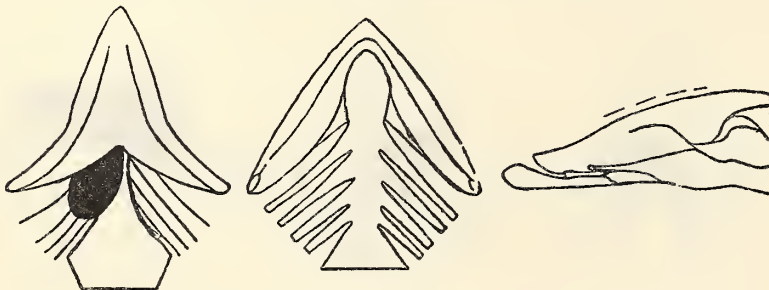


DIAGRAM 24.—Fish 174, *S. fontinalis*, length 20 cm.; type papillar.

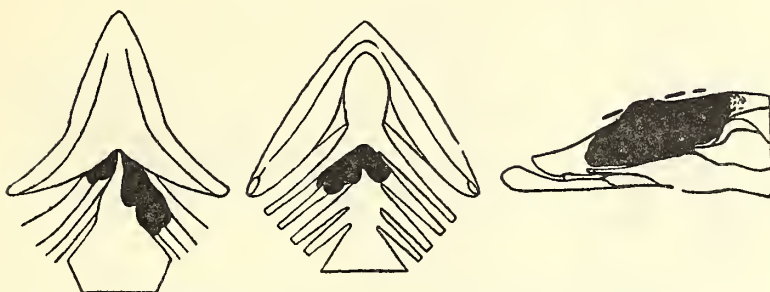


DIAGRAM 25.—Fish 181, landlocked salmon, length 35 cm.; type alveolar.

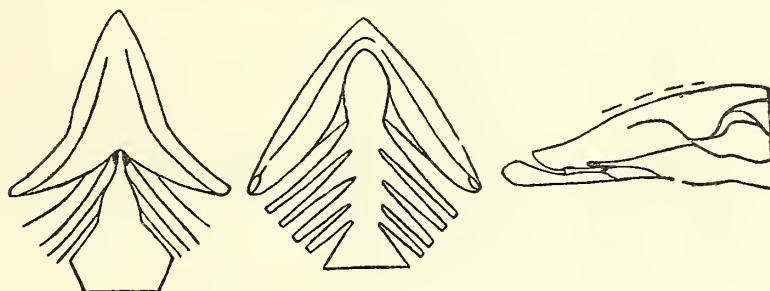


DIAGRAM 26.—Fish 183, *S. fontinalis*, length 15.9 cm.; type alveolar.

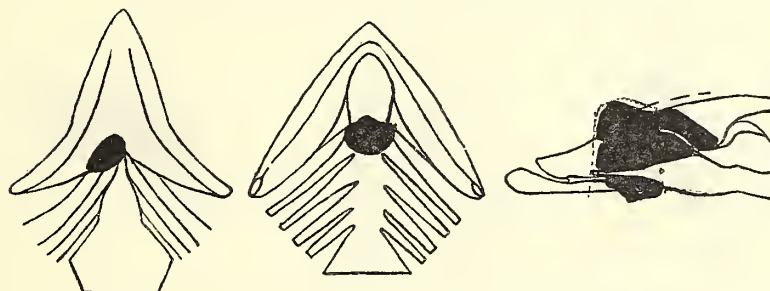


DIAGRAM 27.—Fish 205, hybrid, length 17.6 cm.; type papillar.

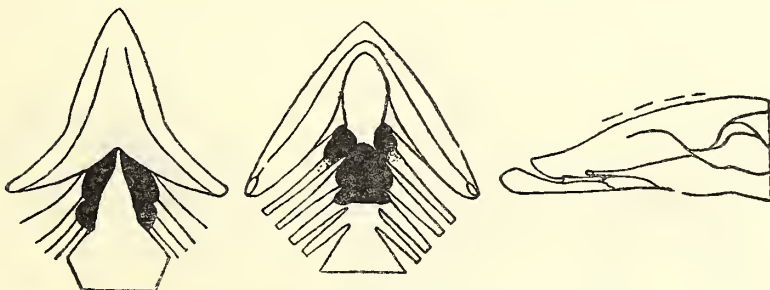


DIAGRAM 28.—Fish 208, hybrid, length 16 cm.; type papillar.

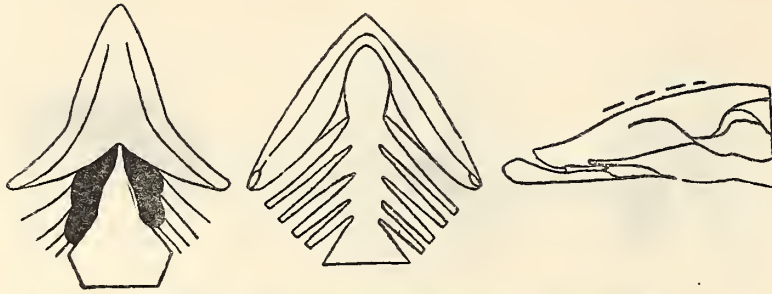


DIAGRAM 29.—Fish 209, hybrid, length 16.3 cm.; type papillar.

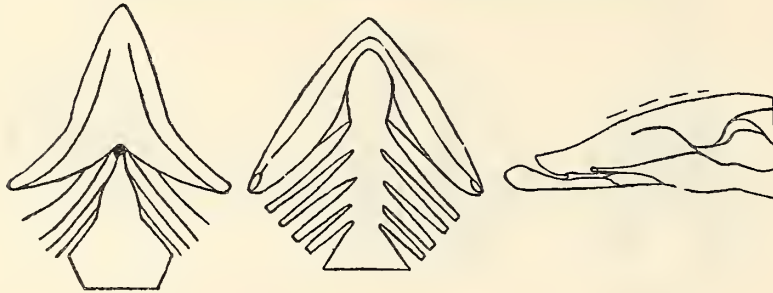


DIAGRAM 30.—Fish 217, *S. fontinalis*, length 9.9 cm.; type alveolar.

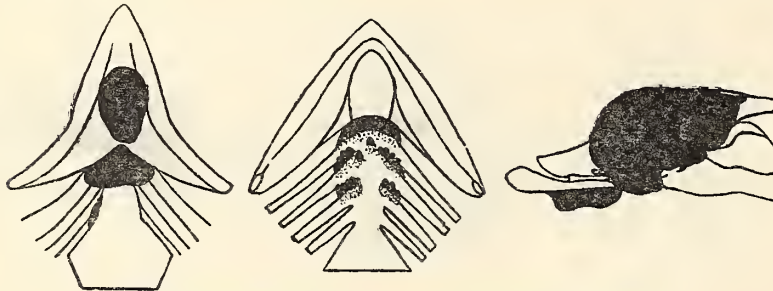


DIAGRAM 31.—Fish 101, *S. fontinalis*, length 21.5 cm.; type papillar.

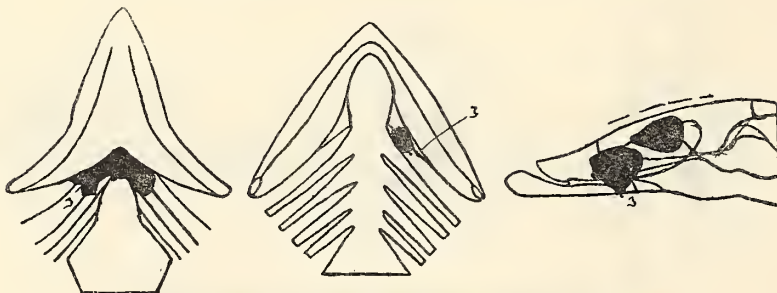


DIAGRAM 32.—Fish 117, *S. salar sebago*, length 14.5 cm.; type papillar.

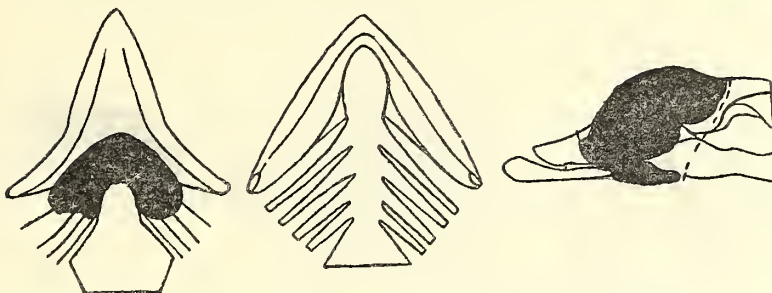


DIAGRAM 33.—Fish 121, *O. gorbuscha*, length 13.5 cm.; type solid.

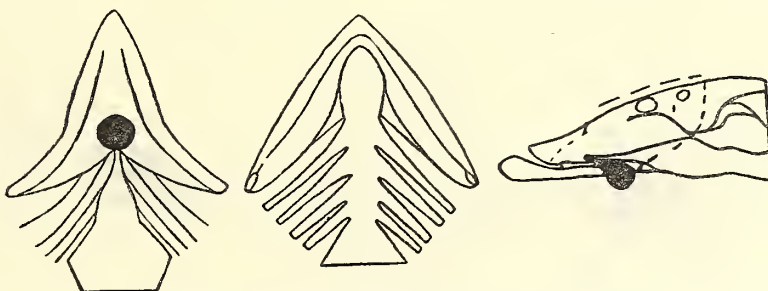


DIAGRAM 34.—Fish 149, *S. fontinalis*, length 23 cm.; type alveolar.

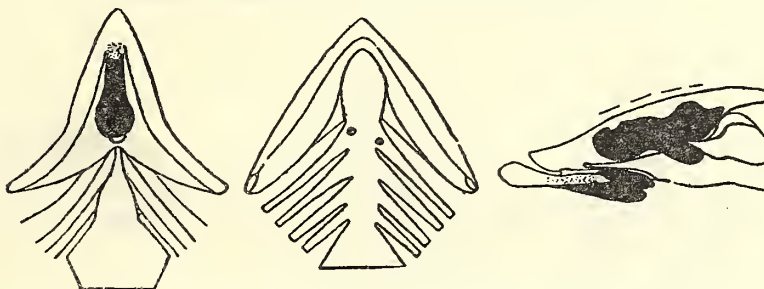


DIAGRAM 35.—Fish 160, *S. fontinalis*, length 21.9 cm.; type alveolar.

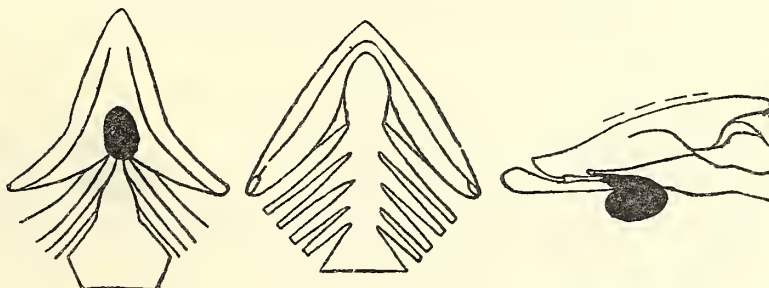


DIAGRAM 36.—Fish 175, *S. fontinalis*, length 14.5 cm.; type alveolar.

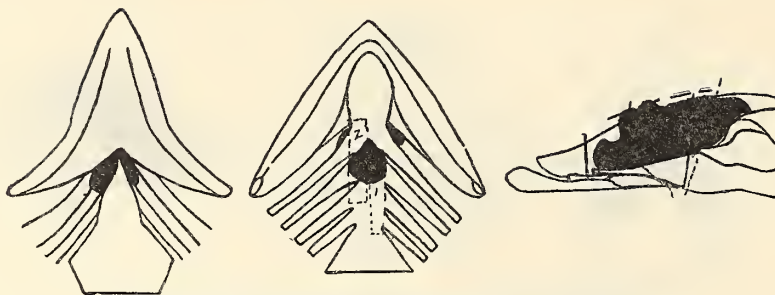


DIAGRAM 37.—Fish 100, *S. fontinalis*, length 24 cm.; type papillar.

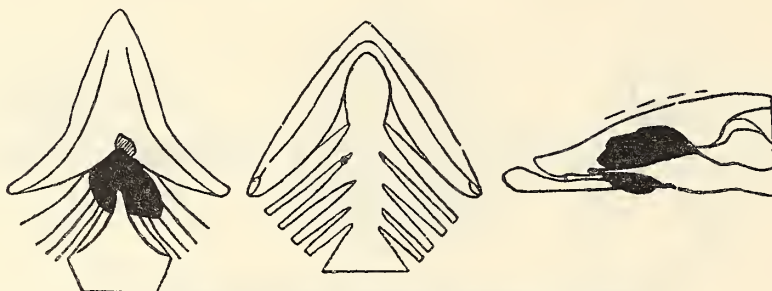


DIAGRAM 38.—Fish 103, *S. fontinalis*, length 24 cm.; type papillar.

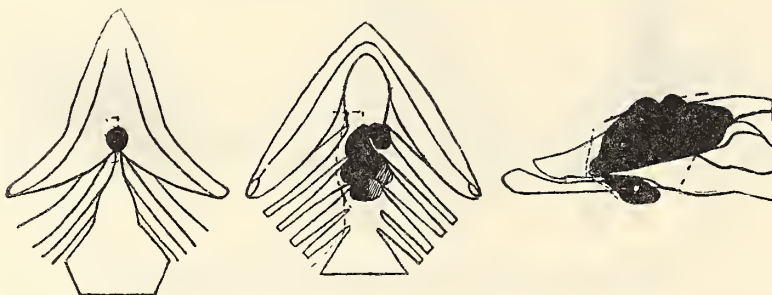


DIAGRAM 39.—Fish 122, humpback, length 14.5 cm.; type solid.

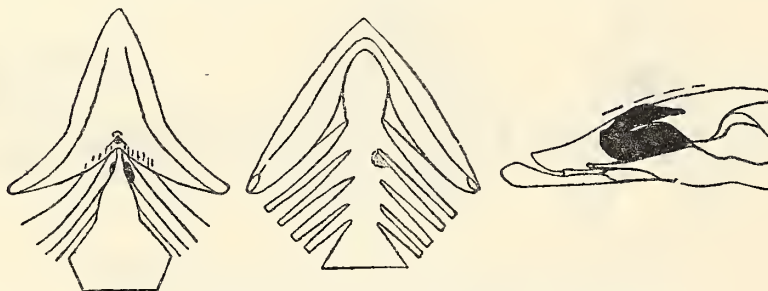


DIAGRAM 40.—Fish 112, *S. salar sebago*, length 15.5 cm.; type alveolar.

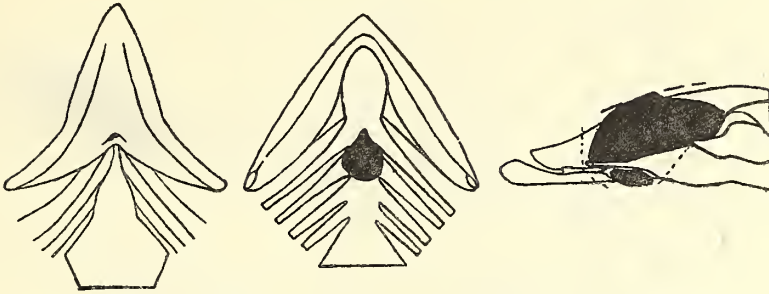


DIAGRAM 41.—Fish 150, *S. fontinalis*, length 16.5 cm.; type papillar.

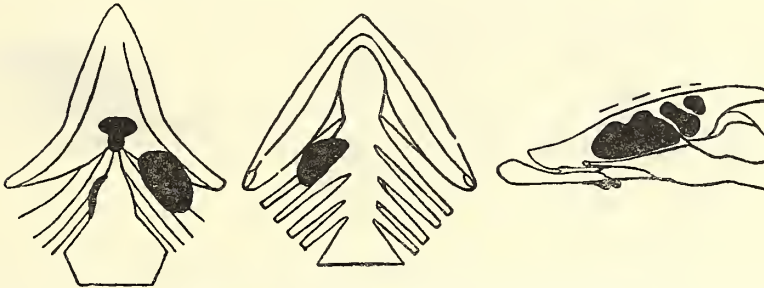


DIAGRAM 42.—Fish 153, *S. fontinalis*, length 24.3 cm.; type alveolar.

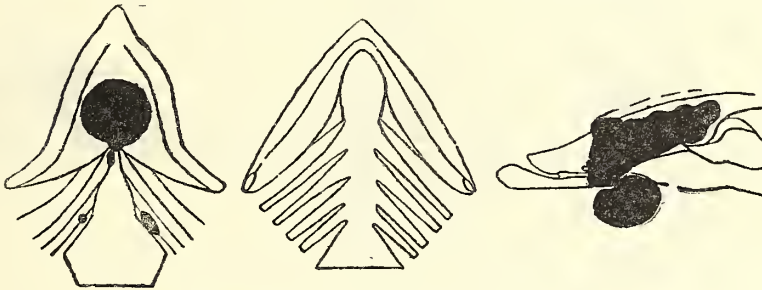


DIAGRAM 43.—Fish 154, *S. fontinalis*, length 18.7 cm.; type alveolar.

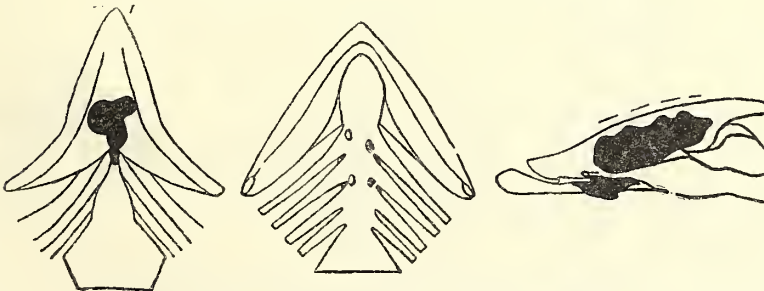


DIAGRAM 44.—Fish 155, *S. fontinalis*, length 24 cm.; type alveolar.

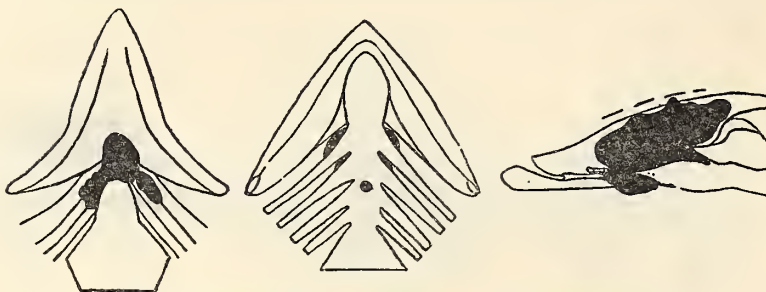


DIAGRAM 45.—Fish 158, *S. fontinalis*, length 18.6 cm.; type alveolar.

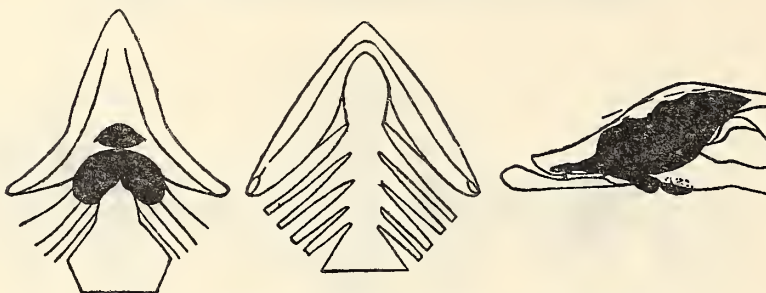


DIAGRAM 46.—Fish 159, *S. fontinalis*, length 21.6 cm.; type alveolar.

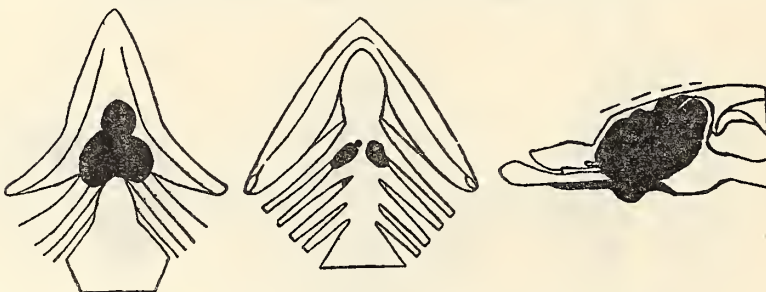


DIAGRAM 47.—Fish 162, *S. fontinalis*, length 23 cm.; type mixed.

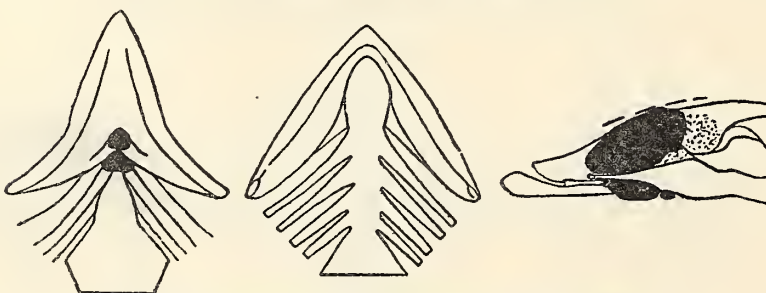


DIAGRAM 48.—Fish 169, *S. fontinalis*, length 23 cm.; type alveolar.

From their position they are subject to mechanical erosion on their ventral surface. When well developed the tumor usually fills and completely obliterates the pit. When the latter is not the seat of tumor growth, it is sometimes completely everted by the pressure of the tumor from the main thyroid region, and almost all trace of it lost, the surface of the skin being stretched smooth in this region.

TABLE I.—CLASSIFICATION OF VISIBLE TUMORS BY LOCATION.

Visible tumor presenting at—	Number.	Visible tumor presenting at—	Number.
Branchial junction.....	4	Pit and floor.....	4
Pit.....	5	Branchial junction:	
Right gill region.....	2	Gill region and floor.....	12
Left gill region.....	1	Gill region and pit.....	4
Both gill regions.....	6	Pit, gill region, and floor.....	3
Floor.....	4	Branchial junction, gill region, pit, floor.....	6
Branchial junction and floor.....	6	Pit and branchial junction.....	1
Branchial junction and gill.....	4	Branchial junction, pit, floor.....	1
Gill region and floor.....	27	Pit and gill region.....	1
Visible tumors examined.....			91

HISTOLOGY.

EARLY STAGE.

Under "Simple Hyperplasia" we have presented evidence which we believe indicates that there occurs in wild and domesticated fish a type of simple hyperplasia which leads to colloid goiter. The first changes in the epithelium in any form of hyperplasia, whether simple or malignant, would be of the same character and thus indistinguishable one from the other. The progress of carcinoma of the thyroid in the Salmonidæ may for convenience be divided into three periods: That in which only microscopic evidence of hyperplasia is discernible; the stage in which the growth of tissue extends sufficiently to produce hyperæmic changes visible in the floor of the mouth—i. e., red floor; and then the period of visible tumors. Histologically no line of demarcation is possible between these various stages. Neither is it possible to distinguish the very first changes in the epithelium at the onset of this disease from simple hyperplasia leading to colloid goiter as we have observed it in the Scotch sea trout which have proven immune to carcinoma of the thyroid.

Normal thyroid tissue in the Salmonidæ is composed of isolated follicles lined with flattened epithelium containing colloid. The follicles are distributed as shown about the aorta in the loose connective tissue.

The first indication of the disease is found in the hypertrophy of individual cells; in a given follicle usually the change affects one or two adjacent follicles, or the only evidence of the beginning of the disease is found in a small group of follicles lined with cubical or columnar epithelium in which the colloid is greatly reduced or entirely absent. Hyperemia of the vessels of the stroma is usually present. In our experiments with wild Wisconsin brook trout, in which fish of varying size and age were taken from the wilderness and placed in the waters of the Craig Brook hatchery, the first evidence of

the disease was found in changes like those above described and affected individual or small groups of follicles lying adjacent to the large arteries. (Fig. 40.) One or two selected protocols of fish in which the disease was experimentally induced and properly controlled show that the action of the agent causing the disease is clearly focal. Budding of the wall of the follicle is early in evidence, presenting an appearance much like that found in the embryo, where the formation of secondary follicles is in progress. But here, instead of this budding, resulting in the formation of isolated follicles of the usual type, we have the formation of irregular groups of cells, tubules, and groups of alveoli of irregular shape, lined with columnar epithelium. In this way new follicles are formed (fig. 36). From the very beginning there is a tendency to infiltration in the surrounding structures. (Fig. 34.)

The fact that the gland of the teleost is not encapsulated was first offered by Gudernatsch as an explanation for the infiltrative character of these growths. This is undoubtedly true so far as the extension of formed follicles between the muscle bundles and into the tissues adjacent to the normal deposits of thyroid tissue is concerned. In this way, with the inauguration of the disease, we find the growth of thyroid tissue into the surrounding structure. Such growth follows in the first instance the lines of least resistance and is in our opinion quite distinct from the phenomenon of the infiltration of adjacent cell structures by individual cells—a phenomenon which is frequently found with the very first evidence of the disease. The cells of the alveoli in this stage have changed from flattened to high columnar, with deeply staining protoplasm, basilar nuclei often vesicular and frequently with many karyokinetic figures. Where the follicles have simply grown between the muscle bundles or against opposing structures, such as bone and cartilage, they are frequently flattened, usually of small size, and closely grouped. Where the follicles are broken through, and groups of individual cells infiltrate the surrounding structures, there is frequently marked proliferation of the interstitial connective tissue. Even in the early stages great variation in the arrangement of the cells is apparent. They form long, narrow tubules, the alveoli more or less irregular in shape, with solid masses of cells and large irregular spaces. The follicles may or may not contain colloid. In the early stage there is generally a marked diminution in colloid. (Fig. 36.)

RED-FLOOR STAGE. .

In this stage the extent of proliferating thyroid is such as to be visible as a slight flush on the floor of the mouth. Histologically the spaces surrounding the vessels are filled with tumor tissue. Bone, cartilage, and muscle are invaded, and the tumor tissue extends toward the gill arches and backward toward the heart. A characteristic of this stage is that the tumor tissue does not seek the paths of least resistance, but infiltrates in other directions. (Fig. 37.) The arrangement is tubular or alveolar in most instances; the epithelium is high and deeply staining. Only occasional follicles with colloid are encountered. There is a well-defined connective tissue reticulum. Karyokinetic figures are numerous and are found in most tumors. (Fig. 35 and 36.)

VISIBLE TUMOR STAGE—STRUCTURAL TYPES.

In the larger tumors one finds a remarkable variation in the histologic picture. The fundamental types may be divided into four—alveolar, papillar, tubular, and solid. In occasional tumors one of these three types definitely predominates. In the 100 tumors selected for study these types occur in the following proportions:

Types.	Per cent.	Fig. No.
Alveolar.....	56	52
Papillar.....	25	61
Solid.....	11	64
Tubular.....	5	63
Mixed.....	3	38

One is struck, however, in the study of these large infiltrating tumors, with the remarkable variety of formation to be found in various regions. One may find in a single tumor areas which may be placed under any one of the designations given. The action of the stimulus upon the thyroid tissue in these tumors appears not only to work irregularly, as will be shown by the advent of nodules of active proliferation and areas simulating hyperplasia, but appears to throw the entire thyroid tissue into such a riot of proliferation that a definite type for the entire tumor is seldom accomplished. The epithelial cells forming the tumor present the greatest possible variety of form and size. The nuclei are usually vesicular, in entire areas of a tumor the cells may present a typical spindle form, thus simulating sarcoma, and in some instances areas of the tumor are made up of a background of spindle cell tissue, through which are scattered small but definite alveoli containing colloid. (Fig. 38.)

In such a tumor we have a picture analogous to the so-called mixed tumor of the thyroid encountered in man. Occasionally tumors may be met in which a large proportion of the tumor is made up of large alveoli packed with solid masses of large cells, deeply staining protoplasm and vesicular nuclei, and frequent karyokinetic figures, presenting the picture of proliferating struma. (Langhans.) (Fig. 39.)

Again, the general predominating type of a tumor may be distinctly papillary, in which large vegetations covered with columnar epithelium and deeply stained nuclei are found projecting into irregular spaces, usually free from colloid. The tendency to papillary formation may be found in almost all of these tumors. Occasionally these papilliform areas are of nodular form, in which case the cells forming the papillary nodule are more deeply stained than the surrounding tubular or alveolar type, which gives them a distinct focal character. (Fig. 45.) This marked tendency to focal or nodular development within the tumors occasionally produces growths in which we have a large mass of tubulo-alveolar structure, with nodules of solid, closely packed areas of intensive proliferation. In figure 40 we have a low-power picture of such a tumor. The tumor mass involves the entire area between the base of the tongue and the pericardial space and extends between the arches to the floor of the mouth, where it projects in a series of large protrusions, has pushed down the muscular structure of the isthmus, protrudes in

the median line at the branchial junction and extends forward into the areolar tissue at the base of the tongue, and presents visible evidence of erosion of the large mass of cartilage at the base of the tongue. The superior, anterior, and protruding posterior portions of this tumor are composed of a network of large alveoli, free from colloid, in which are embedded a number of dense nodular growths. One of these protrudes into the floor of the mouth, a group of larger ones forms the central portion of the tumor, and one or two small ones protrude into the anterior portion of the alveolar structure.

Here we have plainly a distinct focal evidence of proliferation of a much more intense type than that involving the surrounding alveolar tissue growth. The small anterior nodule is found under high power to be composed almost exclusively (fig. 41) of closely packed spindle and oval cells with deeply staining nuclei in which the merest suggestion of an attempt at alveolar arrangement in some of the cell groups may be traced. In the distinct nodule lying in the floor of the mouth the alveolar structure is more apparent, and figure 42 shows a small, distinct nodule of adenomatous type. The margins of these more or less solid nodules in this tumor gradually merge into the loose alveolar structure forming the remainder of the tumor. In some tumors, however, we have found small nodules of closely packed alveoli, the cells of which stain deeply, with closely packed, deeply staining nuclei, the nodule embedded in a reticulum of more open alveolar structure, the cells of which are not in so active a state of proliferation and do not stain so deeply. In many of these nodules expansive growth is evidenced by compression and displacement of the alveoli of the tumor tissue surrounding the nodule. (Fig. 43.)

INFILTRATION.

In another aspect of the nodule one finds definite evidence of infiltration of surrounding thyroid tumor tissue by individual alveoli of the more malignant type. (Fig. 44.) We have here definite evidence of infiltration of thyroid tissue by a nodule of malignant degeneration of more active type. The importance of this finding is that the infiltration in this instance does not deal with anatomical landmarks or adjacent structures but represents a true infiltration, by a more malignant and rapidly growing portion of the thyroid tissue, of surrounding thyroid structure.

A nodular development in the tumors indicates a more intense focal action of the stimulus causing these tumors. It has been suggested that proliferation of the thyroid in these growths in the Salmonidæ is due to a reaction of the tissue to physiological demands. A marked characteristic of physiological hyperplasia is the uniformity with which the entire organ is affected. One of the most prominent characteristics of these growths in the thyroid in the Salmonidæ is intensive local stimulation, which leads not only to nodules within the tumor masses, but gives the visible growth a marked lobulated appearance. If these tumors represented a response to physiological demands, we should expect a more uniform character of the hyperplastic tissue. We should expect all of the thyroid tissue to be affected. In this connection the section of fish 158 is significant. Here we have an extensive tumor (diagram 45, p. 36) involving the entire region between the isthmus and the floor of the mouth, appearing at the branchial

junction and in the gill spaces on both sides, protruding between the first and second branchial arches, and penetrating the floor of the mouth in the median line at the junction between the second and third branchial arches.

Microscopically, this extensive growth is found to infiltrate the surrounding structures, bone, cartilage, and muscle. It may be classified as alveolo-tubular type. In many regions it presents a characteristic solid structure. Only in occasional areas do a few follicles contain poorly staining colloid. In the region of the third branchial arch is found a cross section of bone, in the lumen of which is a group of thyroid follicles of strictly normal appearance. (Fig. 47.) The follicles are of the usual size filled with homogeneously and deeply staining colloid, the epithelium is flattened, protoplasm small in amount, the nuclei stain deeply and homogeneously. A study of the preceding and succeeding serial sections fails to show any opening through the wall of bone. The tumor tissue is in immediate contact with the shell of bone for a considerable extent of its circumference, the remainder is covered with periosteum and dense connective tissue.

The significance of this finding is that here we have a large tumor of tubulo-alveolo-solid type infiltrating the surrounding structures, while lying within the medullary space of the bone structure and included in the tumor tissue is a deposit of normal thyroid tissue which by its appearance, and the presence of deeply stainable colloid, must be in physiological continuity with the metabolism of the fish. That the deposit of normal thyroid within the bone has remained unaltered because it was protected from an agent working from without by being inclosed within the bone is probable, but no less important is the fact that it shows clearly that portions of the thyroid structure in the Salmonidæ may undergo malignant change, while other portions of the thyroid tissue remain strictly normal in appearance and retain their physiological function until, it may be said, as this tumor was very advanced, the last stages of the disease.

A great deal has been said about the significance of the capsule of the thyroid in mammals. Here the evidence of malignancy consists in a breaking through the capsule and infiltration of the surrounding structures. As the thyroid structure of the teleost has no capsule, such a criterion can not be applied, and some have ascribed the infiltrative characteristics of these tumors to the isolated character of the follicles and lack of a delimiting capsule. One of the best evidences of malignancy in the mammalian thyroid is the development of isolated nodules of malignant character within the structure of an enlarged thyroid, and here the evidence of infiltration has not to do with a capsule, but the infiltration of surrounding thyroid structure. A determination of exactly analogous conditions in our tumors indicates that we have in the proliferation of the tumor tissue in the Salmonidæ an expression of genuine malignancy.

Infiltration of bone and cartilage.—The growth of these extensive tumors naturally leads to the erosion and destruction of cartilage and bone. The mere presence of thyroid tissue within the bone spaces of the branchial arches is in itself of no significance. Deposits of normal thyroid tissue are often encountered in the open spaces of both bone and cartilage. The shape of the bony and cartilaginous structure in the floor of the mouth in the teleost is frequently such that the thyroid tissue grows in through small openings in the base of the arches. In many instances, however, we

find total destruction of cartilage and bone and marked evidences of infiltration of the bony and cartilaginous structures by individual cells and groups of cells. (Fig. 48 and 49.)

Infiltration of vessel walls.—Genuine infiltration of vessel walls will serve much the same purpose as infiltration of the capsule in mammals, as deposits of thyroid tissue within the media of the larger vessels has never been encountered. Figures 33 and 50 show a section of the aortic wall stained with orcein, in which the elastic lamellæ of the media are split up and spread out into the adjoining tumor mass as the result of the penetration between the elastic lamellæ of the alveoli of an infiltrating tumor. The aortic wall at this point is reduced to about half the thickness of the uninfiltrated remainder of the circumference. We have here genuine infiltration of the media of the aorta.

Infiltration of muscle.—Besides the growth of the alveoli of tumors between the muscle bundles (fig. 37), we frequently encounter infiltration of individual muscles cells by tumor cells. In these cases the sarcolemma sheath is broken through and we find the isolated cells of the tumor displacing the muscle fiber. (Fig. 51.) The tumor tissue in many instances has lost its alveolar structure, the cells being closely packed together without definite form. There are many instances of genuine infiltration by individuals or groups of cells in the muscle fibers.

Infiltration of the skin.—This is usually best observed in the floor of the mouth. It has been suggested that the breaking through of tumor masses of the outer integument was due largely to pressure, that the epidermis became greatly thinned and ultimately eroded. This is in many instances true where large masses of tumor protrude into the floor of the mouth or where protuberant growths extend downward or outward. In the floor of the mouth, however, we frequently find that the elastic structure of the skin and the epithelial strata overlying it are punctured by small vegetations. Figures 31 and 32 show such growths. Frequently growths penetrating the floor of the mouth will be found to have split up and destroyed the elastic structure of the epidermis without any appreciable thinning whatsoever, the entire thickness of the elastic structure suddenly disintegrating without any evidence of stretching or thinning. (Fig. 46.) It is therefore evident that besides expansive growth, carcinoma of the thyroid in the Salmonidæ presents indisputable evidence of genuine infiltration, such as we encounter in malignant growths in other species.

OTHER OBSERVATIONS.

In 1905, L. Pick published a comprehensive article entitled "Carcinoma of the Thyroid in the Salmonidæ," with 15 illustrations. It is by all means the most important publication on this subject dealing with the histology of these tumors. Pick's material consisted of 10 brook trout obtained from a hatchery, we are led to believe, in the United States. He illustrates five of these fish, one of which exhibited a large infiltrating tumor involving the entire region below the floor of the mouth and the muscular structure of the isthmus (Pick, 1905, fig. 1). Figure 3 shows a small tumor at the branchial

junction. Figure 4, a view from above downward, shows a vegetating tumor in the floor of the mouth. Figure 2 illustrates an isolated tumor in the jugular pit, and figure 5 a tumor in the jugular pit and one at the branchial junction.

Pick's paper is particularly excellent in the thoroughness with which he deals with the histology of these tumors. In fish 1, with the large infiltrating tumor in the floor of the mouth, he recognizes the variegated character of the epithelial structure, distinguishing an adenomatous portion and a follicular portion, both of which he closely describes. He points out the absence of any evidence of a capsule and describes fully and accurately the infiltrating character of the tumor tissue. He notes the extension of the tumor in the lymph spaces of the neighboring muscular fascia, which he describes as being destroyed by the infiltration. Strands of tumor cells which widen into follicles invade the lymph spaces of the adventitia of the aorta. He describes the invasion and breaking up of the tendon of insertion of the muscle of the isthmus. The epithelium of the tumor invades the loose submucous fatty tissue, and the spaces of the dense connective tissue and the tunica propria of the mucosa of the floor of the mouth. Not only are the softer tissues invaded, but he finds that both cartilage and bone are destroyed. This is accomplished by the tumor surrounding the bone growing into the various infoldings of the branchial arches and the cavities of the bone, opening up the capsule of the cartilage, and invasion of the cartilage tissue proper, infiltration between the periosteum and the bone, thus leading to the death of fragments of bone and the formation of sequestra which through the process of decalcification and fibrillation disintegrate.

In his description of fish 3 he shows, in figure 8, the invasion of the mucosa of the floor of the mouth by papillary outgrowths which, in the instance illustrated, shows the formation of small cystlike alveoli within the epithelium of the mucosa. In fish 5 he describes and in figure 9 illustrates the solid type of tumor; in figure 10 is shown the polymorphic nature of the cells of this tumor. In fish 7 he describes portions of tumor with large cystic alveoli, flattened single layer of epithelium and stainable colloid (*struma thyreoidea parenchymatosa colloides*). In fish 8 the papillary type of growth is described.

Pick concludes that these tumors are undoubtedly infiltrating epithelial neoplasms, malignant epithelioma, or in the general sense of Orth's definition, carcinoma. He points out that the diffuse deposit of thyroid tissue does not necessarily become diseased in toto; in fact, that it is more often affected at various points, that the growths are pluri-centric. He thinks that these centers of growth originate simultaneously or at different times, that they may grow more or less uniformly and that in some cases outlying extensions of thyroid tissue become involved, these facts explaining the remarkable variety of form of the tumors, the directions in which they infiltrate, whether upward into the floor of the mouth or laterally into the gill spaces, and the fact that they may be bilaterally symmetrical or unsymmetrical.

He points out the absence of a capsule in any of the tumor fish. He recognizes that several of his tumors have retained very definitely the thyroid structure and speaks of these as presenting the character of parenchymatous struma, although in such tumors the infiltrative character and destruction may be very great, these being tumors of

homotypic character; and that in others the great variation in size of cells and marked deviation from the organal type produce tumors of heterotypic character.

IMPLANTATIONS AND METASTASES.

It is obviously of the greatest importance in a neoplasm of the character of the carcinoma of the thyroid in the Salmonidæ to determine whether or not metastases or possibly implantation may occur. Although infiltrative growth is and will always remain one of the best evidences of malignancy, yet in the last analysis a true neoplasm must present some evidence of metastasis formation or the development of implants. The experimental study of cancer has placed a new significance upon the importance of transplantability. Experimental results with mouse and rat tumors clearly indicate that metastasis formation may be controlled or at least influenced by concomitant immunity, and as the immune phenomena are more outspoken in the more virulent types of cancer, it is not surprising that a neoplasm involving a vital organ like the thyroid, through its early infiltrative growth involving vital structures, might prove the determining factor in the early carrying off of the individual and thus the life of the affected fish might not extend into the period in which metastasis formation more frequently occurs.

The rarity of the occurrence of metastases in any given group of tumors may well be expected. In such a case one or two instances may serve the purpose of definitely fixing the nature of the neoplasm. The occurrence of metastasis in the thyroid carcinomata of fish is certainly rare. The circulation of the fish is not well adapted to the transportation of cells. The region in which transported cells would most easily obtain lodgment would be in the bifurcations of the vessels of the branchial arches, and it is a common occurrence to find isolated growths well away from the median line on these structures, but as deposits of thyroid tissue are located immediately about the aorta many of these growths will be found to be simply outgrowths from the primary mass in the median line. Some of them are, however, so widely displaced from the median mass that they may be looked upon as regional metastases in which the transport of cells would have to be accomplished through the lymph channels. It may be said that growths in this region, however, are not competent to determine the question of true metastasis formation from transport of cells. A region already referred to and one in which the development of tumors is very frequent, occurring in not less than 25 per cent of the studied cases, is the jugular pit. The explanation for these growths is, however, found in the frequent presence of misplaced thyroid tissue. The origin of these deposits has been clearly traced and adequately explained.

Early in our observations we noted that occasional growths upon the tip of the lower jaw were to be seen. (Fig. 28.) This region in the fish is one peculiarly exposed to injury. The fish confined in tanks almost certainly run into the sides of the tanks or the screens and injure the epidermis at this point. These growths at the apex of the lower jaw might be explained by the presence of unusual deposits of thyroid tissue at this point. We have examined, by serial section, this region of the lower jaw in 25 fish, and have never found any trace of normal thyroid in this location. Furthermore,

a careful study of the development of the thyroid in the embryo gives no indication whatever of the likelihood of thyroid tissue being deposited at this point, and in the careful survey of the distribution of the thyroid in wild fish we have never seen any deposits of normal thyroid tissue even so far forward as the base of the tongue. We must, therefore, conclude that there is no evidence that thyroid tissue is ever laid down in this locality.

The anatomical structure at this point is also very unfavorable for the deposit of normal thyroid tissue. The symphysis of the dentaries here is covered only by the periosteum, a thin layer of dense subcutaneous connective tissue upon which rests directly the elastic structure and the epidermis of the outer covering. In fish 61, diagram 1, we find an extensive growth of thyroid tumor springing from the apex of the lower jaw, entirely distinct and separate from the usual growth of tumor about the aorta and extending up into the floor of the mouth. A microscopic examination of the growth of the tip of the jaw and the primary growth in the substance of the isthmus shows that they present much the same appearance, being both alveolar in type and many of the alveoli containing stainable colloid. (Fig. 52 and 53.) The similarity in the primary and the detached growth on the tip of the jaw naturally indicate that we have here to deal with a metastasis.

There is, however, a further possibility, and this is that a growth has developed from an implant finding lodgment upon the prepared site of an injury. We have frequently observed that fish with large protruding tumors in the gill region attempt to free themselves of the outgrowths by rubbing the tumor upon the bottom of the pond. This is evidenced by the frequent observation of tumors which have been worn off in this way. It is quite easy to conceive that fragments of such eroded tumors floating in the water of the pond might find lodgment upon the injured apex of the lower jaw. If this was the origin of this outgrowth on the tip of the lower jaw, the similarity between the primary tumor and the secondary tumor would have to be a matter of coincidence. We feel we may safely conclude that the growths on the tip of the lower jaw are true metastases from primary growths in the usual locality, the lodgment of the cells by way of the circulation being favored by reparative processes at this point, or that the growth is a result of implantation through the medium of the water. From the standpoint of determining the true neoplastic character of these tumors, the evidence would be in either case of about equal value.

A case of still greater importance has to do with a 2-year-old brook trout from the same source, in which a tumor measuring 7 by 8 by 14 millimeters, of pear shape, soft consistency, and dark pinkish color, was found in the lowermost portion of the hind gut or rectum just within the anus. (Fig. 25.) Careful examination shows that the tumor is for the greater part covered by the mucosa of the intestine. It protrudes within the intestinal canal, which is greatly flattened and pushed to one side, and has obviously been obstructed by the tumor. (Fig. 54.) A section made from the wall of the intestine, including the intestinal lumen, well into the tumor, presents on microscopic examination the following conditions:

The tumor is of alveolo-tubular type, the greater proportion of it solid. It involves the muscularis mucosa of the intestinal wall, bundles of muscles derived from this structure running through its substance. In the more open portions of the tumor, alveoli containing colloid may be found. Under higher power (fig. 57) the epithelium of the tumor both in the alveolar and tubular types consists of large cells generally of high columnar type. The protoplasm is deeply stained; the nuclei are vesicular, of basilar location. In some areas marked variation in size and character of the epithelial cells is evident. Karyokinetic figures are not infrequent. The heterotypic nature of the epithelial cells is best seen in the region where the muscular coat of the intestinal wall is infiltrated. (Fig. 57.)

The larger proportion of the tumor is rather regular in formation, homotypic in character. In many places the epithelium is so closely packed that scarcely any evidence of alveolar structure may be made out. The relation of the intestinal lumen to the tumor growth is of peculiar importance. Carefully scanning the tumor under low power a point may be found where the intestinal epithelium spreads out into a single layer upon the surface of the tumor. (Fig. 55.) There is no evidence of transition from the intestinal epithelium into that of the tumor; in fact the marked columnar character of the intestinal epithelium, with its frequent goblet cells, is clearly distinguished against the background of tumor tissue. Upon the surface of the tumor the single layer of epithelium from the intestinal papillæ extends for a considerable distance upon the surface of the tumor, the uppermost portion of which is, however, eroded. Evidences of occasional hemorrhages upon the surface may be found, the apex of the tumor being covered with a distinct clot. In other portions of the tumor the characteristic appearance of alveoli of irregular shape generally filled with colloid is to be found and in this region the tendency to papillary growths within the alveoli is quite distinct. (Fig. 56.) In this region also the structure of the muscularis mucosa is apparent, and the marked infiltrative character of the tumor is here distinctly evident.

The histologic diagnosis of this tumor is to our mind quite clear. It consists of thyroid tissue presenting the characteristics of the alveolo-tubular type of tumor of the thyroid in the Salmonidæ. It furthermore presents in certain areas that tendency to papillary formation which is so frequent in these tumors. The histological picture and the presence of colloid quite clearly determine the nature of this growth. It is greatly to be regretted that through an unforeseen accident the thyroid region of this fish was not preserved. We have no evidence as to the nature of the primary growth in the thyroid region. Although the fish presented no macroscopic evidence of tumor, yet there is little doubt that a primary tumor in the thyroid region existed. The fish was taken from a hatchery in which one of the most outspoken epidemics of the disease we have yet encountered was in full progress. As all of the brook trout of this age succumbed to the disease in the course of two seasons, and as every specimen taken from the pond in which this fish was found presented macroscopic or microscopic evidence of the disease, there is little reason to doubt that we have here to deal with a metastasis from a tumor originating in the thyroid tissue of this fish.

We have expressed our reason for holding that the growths on the apex of the jaw and this growth in the wall of the intestinal tract just within the anus are instances of genuine metastasis formation. We believe that a wider understanding of the natural history of carcinoma of the thyroid of the Salmonidæ will show that a case described by Marine and Lenhart (1911a, p. 470) is more probably a metastasis than a tumor springing from misplaced thyroid. These authors describe an abdominal goiter in a 29-months-old fish. The thyroid mass was round, circumscribed, and measured one by one-half cubic centimeter, was attached to the cardiac end of the stomach by a connective tissue pedicle and extended into the abdominal cavity. The fish had a large ventral tumor histologically identical with the abdominal growth. Because an examination of the visceral regions showed no such deposits of thyroid tissue, these authors looked upon this specimen as an enlarged aberrant thyroid deposit. They also report having seen growths on the tip of the lower jaw in from 2 to 3 per cent of all fish with visible tumors examined by them, and these they also hold to have sprung from misplaced thyroid deposits.

COMPARATIVE PATHOLOGY.

The study of hyperplasia and carcinoma of the thyroid in the Salmonidæ, on account of the great similarity in the changes in the organ of the fish to that occurring in mammals, seems likely to throw important light upon the origin of certain structures which have been the subject of extensive study in the thyroid of mammals. Virchow (1863), Wölfler (1883), Hitzig (1894), and Michaud (1906) have described in the thyroid of man small adenomata, the condition being known as struma nodosa. Virchow held that these nodules developed by proliferation from the follicles of the thyroid. Wölfler held that they developed from misplaced embryonic rests. Hitzig evidently opposed the theory of Wölfler as to the embryonic origin of these nodules and held that they developed by proliferation from the normal tissue of the thyroid, for the reason that in normal thyroids they were never found. Michaud has carefully studied the genesis of these adenomata and agrees with Virchow and Hitzig that they are formed by proliferation from normal structures of the thyroid.

According to Michaud these growths develop by changes in the epithelium of normal follicles, which take on columnar type and through proliferation of the cells form extensions and protrusion of the follicles and finally by budding produce new follicles which become detached from the original. The first changes, which are focal, are restricted by the surrounding stroma, which takes no part in the change. From this point on the nodule grows by proliferation of the structures within it, especially those toward the center. The very first evidence of this change is found by Michaud in the presence in the thyroid structure of long, tortuous clefts or tubes with cubical or columnar epithelium, staining more deeply than the surrounding structures, these tubules having already been noted and described by Hitzig. From these tubules, by the process of budding above described, are developed focal nodules, i. e., struma nodosa.

It will be seen that the description given by Hitzig and Michaud for the development of these isolated adenomata in the mammalian thyroid is exactly like the beginning

changes leading to carcinoma of the thyroid in the Salmonidæ as we have described it. In figure 84 the change from flattened to columnar type, with deeply staining protoplasm, lengthening and flattening of the tubules, closely resemble those found in the mammalian thyroid by Hitzig and Michaud, and, with the exception of the hyperaemia, which is associated with the more intensive changes, in the hyperplasia of the thyroid in the Salmonidæ. The advent of isolated nodular growths, sometimes sharply circumscribed (fig. 45), indicates that focal proliferation of the thyroid tissue in the fish frequently leads to the development of nodules presenting the picture of nodular struma in mammals. The structure of the normal thyroid in the Salmonidæ is so simple and its amount so limited, that a careful study of this structure in all age periods of the fish renders it clear that the advent of tubular structures with columnar epithelium clearly represents a pathological change, and here we are not troubled with the many questions which arise to complicate the study of these structures in the mammalian thyroid. We can, in the thyroid of the Salmonidæ, definitely exclude the idea voiced by Krämer, 1910, that such tubules in the mammalian thyroid were probably originally the remnants of excretory ducts persisting from an earlier period of development of the mammalian thyroid. It is plainly evident from the study of the normal thyroid in the Salmonidæ and the genesis of hyperplasia, nodular growths and fully developed carcinoma, that the changes in this organ are brought about by the action of some agent working focally upon the epithelium of normal vesicles, and we can clearly exclude all possibility of embryonic rests playing a part in the genesis of circumscribed adenomata or cancer.

The evidence adduced on this subject therefore confirms, so far as the evidence is applicable, the conclusions of Virchow, Hitzig, and Michaud that struma nodosa develops as the result of focal change in the epithelium of normal structures of the thyroid. The production of tubules and irregularly distorted spaces lined with columnar epithelium and the process of development of new follicles by budding, as described and illustrated by Michaud, are repeatedly encountered in our specimens, especially in the earliest stages. (Fig. 36.) The theory that carcinoma of the thyroid develops especially from the adenomata of nodular struma and that endemic goiter is the result of a physiological hyperplasia of normal thyroid tissue, finds no support in our study of carcinoma of the thyroid in the Salmonidæ. The theory of Marine that iodine affects alone physiological hyperplastic changes of the thyroid tissue and does not affect these adenomata, and may thus be used as a means of distinguishing between physiological hyperplasia and cancer, is obviously untenable, as we find that iodine, as well as mercury and arsenic, affect not only fully developed carcinoma of the thyroid but where tumors contain individual adenomata these are likewise affected. Well-developed tumors in the Salmonidæ sometimes closely simulate the structures of nodular struma in the mammal. Figure 65 represents such a tumor and may be compared with figure 66, struma nodosa in man. The tumors of the fish frequently contain the so-called Wachstum centra of Aschoff. (Fig. 66.)

Although it may not be wise to go too far in the comparison of carcinoma in the Salmonidæ with carcinoma of the thyroid in mammals, yet inasmuch as we will show

later that at least the first stages of this disease can be induced in mammals through the drinking water, such a comparison at the present time becomes even more profitable than formerly. The final relation of these tumors to tumors in mammals can now be left to experimental investigation; especially the production in mammals of metastasizing tumors would serve to clear up the possible relation between carcinoma of the thyroid in the Salmonidæ and carcinoma of the thyroid in mammals. For the present we consider that we have more firmly established the fact already assumed by Plehn, Pick, and many other investigators, that we are here dealing with carcinoma of the thyroid in fish.

Pick, in his excellent article, after having established the homotypic and heterotypic character of these tumors, compared them with the malignant epithelial tumors of other animals, especially carcinoma of the breast in mice. This analogy of Pick's is well taken and we feel that the progress of experimental cancer research has since demonstrated many other points of analogy, which we shall deal with later. Pick also pointed out that certain degenerative and regressive changes are common both to carcinoma of the thyroid in fish and the epitheliomata of mammals. The impossibility of classifying the different types of carcinoma of the thyroid in fish affords another point of similarity with carcinoma of the breast in mice, where the greatest variety of histological appearance may be found in the same tumor. A still closer analogy, according to Pick, is to be found in the histological character of the growths of the thyroid in fish when compared with similar tumors in man, although from the material at Pick's disposal he had no evidence of metastasis formation, such as we are now able to bring.

One of the most important contributions to our knowledge of the various types of epithelial proliferation of the thyroid structure in man is found in a monograph, based on very extensive material, entitled "On the Epithelial Forms of Malignant Struma," by Langhans (1907), in which this author classifies the various types of malignant growths of the thyroid in man under the following heads:

1. Proliferating struma.
2. Carcinomatous struma, the usual irregular structure of carcinoma.
3. Metastasizing struma.
4. Para struma.
5. Small alveolar, large-celled struma.
6. Malignant papilloma.
7. Squamous epithelioma.

From a comparison of our material with that of Langhans we find that in the fish tumors, areas of proliferation, or in some instances the greater part of the structure of a tumor, may be said to conform to one of three of the six types described by Langhans for man, namely, proliferating struma, carcinomatous struma, and malignant papilloma. Figure 59 illustrates a tumor in which the preponderating type is almost identical in appearance with the type described by Langhans for proliferating struma and may be compared with figure 60, made at the same magnification from one of Prof.

Langhans's original sections which he was kind enough to transmit to us. Carcinomatous struma in man has its analogy in many of the illustrations of fish tumors given. Figure 63 illustrates the papillary type of carcinoma in the Salmonidæ, which may be compared with figure 27, plate 6, of Langhans's article, illustrating the type known as struma of Geisslar. Langhans's group 6, malignant papilloma, finds its counterpart in many of the fish carcinomata, papillomatous areas occurring in almost all tumors. Figure 61 illustrates a tumor of almost pure papillomatous type and may be compared with figure 62 from one of Prof. Langhans's sections of malignant papilloma in man and illustrated by him as figure 32, plate 7, of his monograph.

Pick was of the opinion from his material that carcinoma of the thyroid in the Salmonidæ was a condition superimposed upon endemic goiter and referred to the occasional observation of malignant growths in man upon the basis of preexisting nonmalignant struma. He suggested that endemic goiter might be distinct from, but was the predisposing factor in, carcinoma of the thyroid in fish.

There is no point at which it is possible for us to draw a line between what might be called endemic goiter in the salmonoid fishes and carcinoma of the thyroid. Whichever interpretation one may desire to put upon this process, endemic goiter and carcinoma of the thyroid in the Salmonidæ are one and the same thing. Viewed in the light of modern cancer research, it appears to us that the term carcinoma is in every respect the more suitable. The first positive results obtained by us in dogs and rats must, for the present, be classed as diffused parenchymatous struma; but as Bircher has already produced nodular struma in his rats, and it is well known that such adenomata of the thyroid develop into what is called cancer of the thyroid, it appears to us quite possible that further experiments may show that in mammals experimental parenchymatous and nodular struma are but the early stages of the process which is called cancer of the thyroid.^a

^a At the meeting of the Freiburger medizinische Gesellschaft June 3, 1912, Prof. Aschoff demonstrated certain preparations of fish and dog thyroids which had been transmitted to him by us. The report of this meeting in the *Deutsche Medizinische Wochenschrift*, no. 25, June 20, 1912, contains certain inaccuracies. Prof. Aschoff is reported as stating that Marine and Lenhart were the first to produce struma in fish experimentally, and spoke of our work as a repetition of such experiments. In none of the publications of Marine and Lenhart is such a claim made. We do not know of any investigators having had the facilities or opportunity to carry out experiments of the kind detailed in this report, requiring, as they do, wild fish taken from regions free from the disease and introducing them into a hatchery under conditions with proper controls to demonstrate that they have acquired the disease. As this incorrect report has been quoted by Schittenhelm and Weichardt in their monograph on endemic goiter in Bavaria, it seems desirable to make this statement.

In their quotation of Prof. Aschoff's remarks these authors state that Aschoff emphasized the similarity of our tumors in fish with the pathological findings in Basedow's disease in man, and that he could not support our view that the fish struma was carcinoma. From the protocol of the meeting quoted it does not appear that he expressed himself so positively as this. He demonstrated the similarity of the preparations with Basedow's disease in man, but this must have applied to the sections of the thyroid enlargement in dogs, and not the fish tumors. This report quoted the fact that iodine, as shown by Marine and Lenhart and confirmed by us, when added to the water, influenced the fish tumors, this fact appearing to be opposed to our interpretation that the fish tumors were cancer, and it did not emphasize the fact that sublimate and arsenic produced the same result, as opposed to this interpretation.

In this connection we would state that in March, 1913, Prof. Aschoff spent a day at our institute in Buffalo, and after carefully studying all of the preparations upon which this monograph is based, including the specimens of metastases, stated that he now holds, in accord with us, that the tumors of the thyroid in the Salmonidæ are carcinoma.

OCCURRENCE OF THE DISEASE UNDER WILD CONDITIONS.

It is through the domestication of trout that attention was first attracted to thyroid disease in fish, and it is from this source that nearly all material and data have been derived, both in this country and in Europe. Nevertheless, the same thyroid process has been identified with certainty among adult fish living in open natural waters.

The most important example of the kind at hand is a whitefish from Lake Keuka, N. Y. This fish, of which the head alone came to our hands, is a member of the genus *Coregonus* of the Salmonidæ and belongs probably to the common species of whitefish of Lake Keuka, *Coregonus clupeiformis*. (Fig. 67.) It was reported as about 60 centimeters in length, probably a female, though the sex was not definitely determined, was caught December 3, 1909, in water about 15 meters deep, and was preserved in formalin about two days later. The tumor, which is described in detail below, is of good size and shows the typical structure common to this growth in the other salmonoid species considered.

From the museum of the University of Buffalo has come to us a brook trout (*S. fontinalis*) having a large thyroid tumor. (Fig. 69.) The fish (diagram 23, p. 30) is a female 17 centimeters in length and was caught by Prof. Herbert M. Hill in 1902 from Hosmers Creek, near Sardinia, Erie County, N. Y. About 3 miles of this stream constituted a fishing preserve of the nature of a wild stream. It had for several years prior to this time been stocked with 5,000 to 10,000 fingerling trout, all obtained from the New York State Hatchery at Caledonia, N. Y. Some fry of the same species were also obtained from the same source and were kept in a pond adjacent to the creek where they were reared to fingerling size and then liberated in the creek. No artificial feeding of any kind was done in the stream and the fish in question was either planted as a fingerling, or possibly as fry from the Caledonia hatchery, or was possibly a descendent of some few wild fish which occupied the stream before systematic stocking was commenced. It is more probable that the fish was originally a fingerling sent from Caledonia. From its size it was probably not under 2 years of age.

The tumor occurring in the wild living whitefish is found on inspection to protrude in both gill spaces and between the first and second gill arches in the floor of the mouth. It infiltrates the structures below the floor of the mouth beneath the first and second branchial arches. (See diagram 16, p. 28, and fig. 67.) Under the microscope the tumor presents areas of vesicular type. The alveoli are small, but few of them contain stainable colloid. The bulk of the tumor is made up of areas of closely packed deeply staining islands of cells, presenting the merest suggestion of alveolar structure. The cells are closely packed, the nuclei vesicular, the protoplasm deeply staining. Throughout the tumor there are evidences of karyorrhexis. The tissue presents the appearance of not having been freshly preserved, but the histological characteristics are sufficiently discernible. The nuclei are vesicular, and nucleoli and karyokinetic figures are quite frequent. In some areas the cells are so closely packed as to present the appearance of spindle-celled tissue. The whole presents the characteristic picture of small alveolar carcinoma. The infiltrative characteristics

are best observed in the wall of the large vein, where we find the cells in small groups slightly suggesting an alveolar structure where they have penetrated into the media of the venous wall. Shrinkage owing to fixation accentuates the chopped out appearance of the media. (Fig. 68.) In studying the various sections in which this vein is included one finds a point at which the venous wall is greatly thinned, and at this point extensive hemorrhage into the surrounding tumor structure has occurred. In the same section groups of tumor cells are to be found in the venous lumen. (Fig. 69.) We have here penetration of vessel walls by the tumor cells. Unfortunately, owing to the fact that we had only the head of this specimen to study, we do not know whether the viscera contained metastases or not.

In the brook trout from Hosmers Creek, N. Y. (diagram 23, p. 30), the tumor presents itself in the gill spaces on both sides of the isthmus, on one side shaping itself into a mass the size of a hazelnut. Protrusion in the floor of the mouth is visible between the first and second gill arches on the side of the large tumor and in the median section it infiltrates the region below the first and second gill arches. The fish is preserved in alcohol. Fixation is moderately good. The section of the tumor measures 11 by 9 mm. On macroscopic inspection of the section a deeply staining, sharply defined nodule measuring 6 by 8 mm. is clearly discernible embedded in a more lightly staining tumor mass. Inspection under low power shows that there is a distinct difference in the appearance of the surrounding tumor and the nodule, the nodule being separated from the tumor by a well-defined compression capsule. (Fig. 70.) The outlying portions of the tumor are for the greater part composed of small alveoli, somewhat loosely arranged, with occasional larger alveoli of irregular shape and marked columnar epithelium. Wide venous channels are frequent in this portion of the tumor. Within the capsule of the above-described nodule one finds the whole made up of somewhat loosely arranged islands, strands, and masses of cells. The central portion of the nodule presents wide venous sinuses without delimiting intima and areas, which are no doubt the result of hemorrhage. Under high power one finds the cells in certain portions of the nodule to be so arranged as to suggest small alveoli, but for the greater part, especially in the well-preserved marginal portions of the nodule, the cells present a distinct spindle character, and great variability in size of the nuclei, which are vesicular with one or two nucleoli. The protoplasm of the cells stains deeply, is rather sparse, and karyokinetic figures are very numerous. Certain areas may be found in which the spindle character of the cells is so pronounced as to suggest the diagnosis of spindle-celled sarcoma. (Fig. 71.) Gradual transitions of such areas into an arrangement of cells clearly showing their derivation from the poorly formed alveoli indicate their character. We have here a nodule of malignant tumor growth in a mass of tumor tissue of less malignant appearance, carcinoma solidum simulating spindle-celled sarcoma.

In June, 1913, a large landlocked salmon (*S. sebago*) with a large thyroid tumor was caught in Sebago Lake, Me., by Dr. Charles F. Parker, of North Windham, Me. Dr. Parker recognized the nature of the growth and forwarded it to us through Dr. W. C. Kendall, of the Bureau of Fisheries. The fish was about 4 years of age, measured 23

inches in length and in its rather emaciated condition weighed 4 pounds. A salmon of this length in health should weigh 6 to 8 pounds. A large thyroid tumor involved the whole gill region, vegetating in the floor of the mouth and presenting on the ventral surface several cystic lobes which kept the gills and gill covers well distended. (Fig. 72.)

Sebago Lake is located in the southwestern part of Maine. It has an area of about 45 square miles and a general depth of 316 feet. It has but few shoal places, the depth of water often reaching close to the shores, which are for the most part rocky, save in a few shallow coves. The lake has little aquatic vegetation; the water is regarded as unquestionably pure and is the source of supply for the city of Portland. While the fish had been living in a wild state for two or three years, it was originally planted from a fish hatchery, where it may have contracted the disease. Microscopic inspection of this tumor (see fig. 75) shows it to be almost entirely of the alveolar type, showing at the center areas of cystic colloid degeneration.

These four tumor-bearing fish were living under wild natural conditions when taken. All can be related more or less remotely to fish culture. They were taken from waters in inhabited regions, in which fish culture has been practiced for years, and these waters had frequently received the products of hatcheries. The trout inhabited a stocked stream, and was possibly the product of a hatchery and fed artificially, or was descended from fish so treated. The landlocked salmon was probably planted from a hatchery. No whitefish are fed artificially nor reared to maturity in domestication. The product of their artificial propagation is planted soon after hatching. The most that may be said, therefore, as far as the relation of this tumor-bearing whitefish to domestication is concerned, is that it may have been artificially hatched, planted before feeding, and was living in a large lake which received the drainage from a large trout hatchery and breeding establishment at which the thyroid disease was endemic and epidemic. It was taken within 5 miles of the point of entry of this drainage inflow.

In one of the small lakes of the Adirondack Mountains of New York, which have been stocked with trout from hatcheries, anglers occasionally report the taking of fish with visible tumors at the throat.

In Europe Hofer (1904, p. 194) reports the disease in wild lake trout (*Trutta lacustris*) living in the Mondsee. Dr. Plehn informs us that occasionally trout with thyroid tumors and living under wild conditions in the streams of Bavaria are sent to the Bavarian Fisheries Biological Station for examination.

OCCURRENCE AND COURSE OF THE DISEASE UNDER DOMESTICATION

DISTRIBUTION OF THE DISEASE IN UNITED STATES HATCHERIES.

The thyroid tumor among fishes is undoubtedly of wide distribution. We believe it occurs almost universally where trout are made the subject of artificial propagation and rearing under the ordinary conditions of fish culture in the United States. A complete canvass of all the trout-breeding establishments in the country has not yet been made, but such an investigation would beyond question indicate the distribution of the disease as coextensive with trout culture. The following list gives the places

at which, from an adequate examination of material, the disease is definitely known to exist or to have existed in an advanced stage as expressed by the exhibition of visible tumors.

District of Columbia.

Iowa: Manchester.

Maine: Craig Brook, Auburn.

Michigan: Paris; Northville.

Missouri: Neosho.

Montana: Bozeman.

New Hampshire: Nashua.

New York: Bath; Margaretville and other hatcheries.

Pennsylvania: Spruce Creek, Glen Eyre.

South Dakota: Spearfish.

Virginia: Wytheville.

Vermont: Roxbury; St. Johnsbury.

Washington: North Yakima.

West Virginia: White Sulphur Springs.

NAMES OF SPECIES AND HYBRIDS.

While the disease primarily and chiefly is found in the brook trout, it has been observed among all the following species and hybrids in the United States. Two of these, the brown trout and Loch Leven trout, are introduced species, and one—the whitefish—belonging to a subfamily of the Salmonidæ, is not the subject of fish culture as an adult and is represented by only one specimen bearing a tumor, this being a wild fish from a lake. It is quite certain that this list will be much extended as fast as other species of salmonoids are brought under domestication. The single species which, though bred artificially, can not yet be included among the species subject to thyroid carcinoma, is the sea trout (*Salmo trutta* Linnaeus), introduced into the United States as the Scotch sea trout.

American brook trout; square-tail trout; redspot trout;

speckled trout.....*Salvelinus fontinalis* (Mitchill).

Rainbow trout.....*Salmo irideus* Gibbons.

Landlocked salmon; Sebago salmon; Schoodic salmon....*Salmo sebago* Girard.

Loch Leven trout.....*Salmo levensis* Walker.

Brown trout; von Behr trout.....*Salmo fario* Linnaeus.

Atlantic salmon.....*Salmo salar* Linnaeus.

Great Lakes trout; lake trout; Mackinaw trout; namaycush

trout; longe; lunge; togue; laker.....*Cristivomer namaycush* (Walbaum).

Humpback salmon.....*Oncorhynchus gorbuscha* (Walbaum).

Common whitefish.....*Coregonus clupeiformis* (Mitchill).

Hybrid salmon:

Female silver salmon.....}*Oncorhynchus kisutch* (Walbaum).

Male humpback salmon.....}*Oncorhynchus gorbuscha* (Walbaum).

Female silver salmon.....}*Oncorhynchus kisutch* (Walbaum).

Male chinook salmon.....}*Oncorhynchus tshawytscha* (Walbaum).

Female blueback salmon.....}*Oncorhynchus nerka* (Walbaum).

Male humpback salmon.....}*Oncorhynchus gorbuscha* (Walbaum).

Female humpback salmon.....}*Oncorhynchus gorbuscha* (Walbaum).

Male blueback salmon.....}*Oncorhynchus nerka* (Walbaum).

Female brook trout.....}*Salvelinus fontinalis*.

Male landlocked salmon.....}*Salmo sebago*.

Hybrid trout:

American brook trout.....}*Salvelinus fontinalis*.

American saibling or sunapee trout.....}*Salvelinus aurcolus* (Bean).

Besides the American brook trout and the rainbow trout introduced into Europe, the following European species, at least, have been observed as the subject of thyroid carcinoma in Europe:

Atlantic salmon.....	<i>Salmo salar</i> Linnæus.
Forelle; Bachforelle; brown trout, yellow trout, brook trout, river trout, etc.....	<i>Salmo fario</i> Linnæus.
Loch Leven trout.....	<i>Salmo levensis</i> Walker.
Seeforelle or lake trout.....	<i>Salmo lacustris</i> Linnæus.
Ombre chevalier, European charr or saibling.....	<i>Salvelinus salvelinus</i> (Linnæus). [Salvelinus alpinus (Linnæus) of most authors.]

GEOLOGICAL FORMATION AT FISH HATCHERIES.

That the distribution of goiter possesses a definite relation to the geological formation has been repeatedly advanced and denied. McClellan in 1837 pointed out the predisposing quality of the mountainous limestone and the nagelfluhe. The principal exponent of this theory in Europe has been H. Bircher (1883). According to this author the greatest concentration of goiter is found in the Molasse highland. The Tertiary formation also predisposes to goiter, whereas the Jurassic formation and the primary formation of the Alps are free from the disease. Kocher (1889), who with the assistance of 25 of his scholars examined 76,606 school children between the ages of 7 and 15 years, was not able to justify these conclusions of Bircher, as he found that the Jurassic formation was in no way free from goiter, neither was the fresh-water Molasse. Recently Hesse (1911) in a study of the distribution of goiter in the Kingdom of Saxony, was able only in part to confirm the theory of Bircher, as he found next to the highest percentage of the disease in the Eibenstock granite and the highest in the eruptive Muscovite gneiss, both of which are formations that according to Bircher should be free from the disease. Schittenhelm & Weichardt, in the study of goiter in Bavaria (1912), found that one of the most extensive distributions of goiter in that country was in the Bavarian forest, which lies upon the primary granite formation. These authors conclude that the geological formation is not a primary determining factor in the endemic distribution of goiter, but that the infection of the water supply is. The distribution of goiter in the mountainous southern portion of Bavaria, as well as in Switzerland, they consider to be due to certain conditions depending upon the mountains themselves and not their geological formation as such.

McCarrison in his analysis of conditions in the goitrous regions of Chitral and Gilgit in Northern India finds that the water supply of the Chitral district comes from metamorphic rocks consisting mainly of gneiss and slate and to a lesser extent of limestone. There are, however, certain large outcrops of limestone, and it is from these that the most goitrous villages derive their water supplies. Likewise the highly goitrous villages of Gilgit are supplied by water from a valley which contains a considerable outcrop of limestone. These results are likewise at variance with the theory of Bircher concerning the influence of geological formation.

Dieterle (1913) after a personal examination of a series of goitrous localities in Switzerland comes to the conclusion that neither the geologic formation upon which

goitrous regions are located on the geologic formation from which the water supply springs is the determining factor in the incidence of goiter. He has found regions located upon and supplied with water from pure Jura formation, with from 12 to 40 per cent of goiter, and comes to the conclusion that the boundaries of localities in which endemic goiter occurs are purely geographic, such as certain valleys, along certain rivers, or the sides of certain mountains.

To determine whether there is any connection between the geological formation at the various hatcheries of the Government where trout are bred and the endemic conditions existing in most of them, we have obtained from the United States Geological Survey a statement concerning the formation at most of the centers of fish culture throughout the country. All the data are included here, whether the station concerned is engaged with trout culture or not. In some cases only general information is available.

No correlation between geological formation and the occurrence of thyroid disease is at present even suggested from the data at hand, which is here shown for purposes of record in view of its possible future value. Most of the water supplying stations subject to thyroid disease arises among the geological formations of primary order. Only one is secondary (Triassic) and only a few tertiary and quaternary.

ALASKA.

Yes Bay.—Crystalline schists, probably Carboniferous.

ARKANSAS.

Mammoth Springs.—Probably in Proctor or Potosi limestone. Cambrian system.

CALIFORNIA.

Baird.—Baird formation. Carboniferous system. This underlies a bluff of the Carboniferous McCloud limestone.

Battle Creek.—Tuscan tuff with some lava beds. Tertiary.

Mill Creek.—On border of alluvium of Sacramento Valley, and of Tuscan tuff and lava. Tertiary age.

COLORADO.

Leadville.—Crystalline rock; pre-Cambrian age.

GEORGIA.

Bullochville.—Formation not known. Probably granite and gneiss. Archean gneiss.

ILLINOIS.

Quincy.—Burlington and Keokuk limestones; Carboniferous age.

Meredosia.—Glacial sand and clay. One hundred feet more or less below the surface is Carboniferous limestone. Same as at Quincy.

IOWA.

Manchester.—Devonian limestone with chert nodules.

Fairport.—At contact of Carboniferous shales on Devonian limestone.

MAINE.

Boothbay Harbor.—Schists and gneisses with dikes of granite. Age unknown.
Craig Brook (East Orland).—Granite. Silurian or Devonian age.
Grand Lake.—Mica schist. Age unknown. Cut by granite of Silurian or Devonian age.
Green Lake.—Granite. Silurian or Devonian age.
Lake Auburn.—Mica schists. Age unknown. Cut by granite of probable Ordovician age.
Lake Sebago.—Granite and granite gneiss. Probably Silurian or Devonian age.
Portland.—Largely quartzose schist. Age unknown.
York.—Volcanic tuff and lava flows cut by some granite. Age unknown.

MARYLAND.

Havre de Grace.—Potomac formation. Carboniferous age.
Bryan's Point.—Talbot formation. Quaternary system.

MASSACHUSETTS.

Woods Hole.—Pleistocene glacial gravels.
Gloucester.—Probably Rockport granite. Carboniferous age.
East Freetown.—Granite. Probably Paleozoic age.
Hartsville.—Stockbridge limestone next to Cheshire quartzite. Cambrian age.
Plymouth.—Pleistocene glacial gravels and sands.

MICHIGAN.

Northville.—Cold Water shale. Carboniferous age.
Alpena.—Antrim shale. Devonian age. Has a little gas.
Charlevoix.—Antrim shale. Devonian age.
Detroit.—Antrim shale and Traverse limestone. Devonian age.
Sault Ste Marie.—Lake Superior sandstone. Cambrian age.

MINNESOTA.

Lester Park, Duluth.—Lavas of Keeweenawan series. Algonquin age.
Homer.—Immediately underlain by St. Croix sandstone, bluffs to south are St. Peter sandstone, Shakopee limestone, Jordan sandstone, and St. Lawrence limestone. Copious spring waters come from these sandstone formations. The St. Lawrence is of Cambrian age; the other of Ordovician age.

MISSISSIPPI.

Tupelo.—Pleistocene sands resting upon sandy portion of Selma chalk. Cretaceous age.

MISSOURI.

Neosho.—Boone limestone. Carboniferous age.

MONTANA.

Bozeman.—Neocene lake beds. Tertiary age.

NEW HAMPSHIRE.

Nashua.—Sand beds of glacial lake. Quaternary age.
Lake Sunapee.—(East side) Granite; age unknown. Heavy cover of glacial gravel; quaternary age. (West side.) Formations unknown.

NEW YORK.

Bath.—Chemung formation. Devonian age.

Buffalo.—Salina formation, Silurian age, and Onondaga limestone and Hamilton shale, Devonian age.

Caledonia.—Onondaga limestone and Oriskany sandstone, Devonian age; Salina shale, Silurian age.

Cape Vincent.—Trenton limestone. Ordovician age.

Chautauqua Lake.—Chemung formation. Devonian age.

Cold Spring Harbor.—Glacial gravel and sand. Quaternary age.

Constantia.—Medina sandstone. Silurian age.

Margaretville.—Catskill formation. Devonian age.

Old Forge.—Mica gneiss. Archean age.

Saranac Lake.—Granite, gabbro, gneiss, and schist. Archean age.

NORTH CAROLINA.

Edenton.—Sand and clay. Quaternary age.

OHIO.

Put-in Bay.—Lower Helderberg limestone. Devonian age.

OREGON.

Clackamas.—Volcanic breccia; probably Tertiary age.

Cazadero.—Volcanic breccia; probably Tertiary age.

Willamette River.—Flood plain sand and clay, Quaternary age; Sandstone, Eocene age.

Rogue River.—Formation unknown.

PENNSYLVANIA.

Bellefonte.—Trenton limestone. Ordovician age.

Freeland.—Coal measure sandstone and shale. Carboniferous age.

Weissport.—Hamilton shale. Devonian age.

Spruce Creek.—Trenton limestone. Ordovician age.

SOUTH DAKOTA.

Spearfish.—Spearfish formation. Triassic age.

TENNESSEE.

Erwin.—Honaker limestone. Cambrian age.

TEXAS.

San Marcos.—Del Rio formation. Cretaceous age.

UTAH.

Provo Valley.—Mesozoic rocks; mainly shales of Mesozoic age.

VERMONT.

Groton.—West part of town in granite. Age unknown. East part in mica slate; probably Ordovician age.

Sharon.—Mica schist; probably Ordovician age.

St. Johnsbury.—Mica schist; probable Ordovician age, with much glacial gravel of Quaternary age.

Swanton.—Trenton limestone. Ordovician age.

VIRGINIA.

Wytheville.—Shaly limestone. Cambrian age.

WASHINGTON.

Baker Lake.—Limestones and schists to the south and volcanic rocks to the north and west. Age unknown.

Birdsview.—Schists partly ferruginous. Age unknown.

Little White Salmon River.—Basalt. Late Tertiary age.

Big White Salmon.—Basalt. Late Tertiary age.

WEST VIRGINIA.

White Sulphur Springs.—Romney shale. Devonian age.

WISCONSIN.

Bayfield.—Lake Superior sandstone, Cambrian age, deeply buried under glacial lake clay. Quaternary age.

Madison.—Madison sandstone, Cambrian age, under heavy cover of glacial gravel.

CHEMISTRY OF THE WATER SUPPLIES.

There are no very definite chemical standards by which the fish-cultural value of a water may be predetermined without the test of experience with fishes. The ordinary sanitary analysis is of almost no value, the showing with respect to dissolved air gases, which are of primary importance in fish culture, being usually omitted. As for a mineral analysis, it is difficult to interpret it in fish-cultural terms since fishes thrive in waters of such varied chemical content that conclusions can not be drawn from a statement of the inorganic materials dissolved, unless they show the water to be so heavily mineralized that it is no longer fresh, or unless it contains the metals known to be highly poisonous to fishes. Even in the latter case special determinations must be made and large quantities of water used, since some metals, for instance, mercury and copper, are fatal to salmonoids in dilutions far beyond detection in ordinary routine mineral analysis.

In order to lay a foundation for the possible establishment of fish-cultural standards in water analysis, by long fish-cultural experience with waters whose chemical constitution was determined, the Bureau of Fisheries has had analyses made of many waters used to supply its various stations for the propagation of fish throughout the country. These analyses have been made by the Bureau of Chemistry, Department of Agriculture. Since not all these stations engaged in trout propagation whose water supplies have been examined chemically have been thoroughly investigated to determine their status with respect to thyroid disease, it is not possible to divide them into those which are subject to and those which are free from the disease, if, indeed, there are any belonging unequivocally to the latter class. We have therefore shown only the results (table II) for waters supplying such stations as are known to have the trout thyroid disease endemic, save the last two (no. 11737 and 11738), which supply the State hatchery at Cold Spring Harbor, N. Y., and one of which appears to be at present free from the disease. By a scrutiny of the mineral content of this water at the latter station, nothing distinctive is to be found. It is low in total solids and therefore very lightly mineralized; the chlorids, sulphates, silicates, and bicarbonates of the common earth metals make up the bulk of the residue. These statements apply equally to many of the waters in which

the disease is developed. It is in our opinion highly improbable that any of the factors in causation of the disease are to be found among the variations of the concentration in which the common earth salts and other matter are found in these waters.

None of the analyses shown in table II disclose any trace of iodine or bromine, but only ordinary volumes, as a single liter, were devoted to the reactions for these elements. In order to test further the presence of these elements in the water of the Craig Brook station, where a large part of our data has been obtained, we have had two samples of 15 liters each used entirely by the Bureau of Chemistry for determining iodine and bromine in two sources of water at the Craig Brook station. The Craig Pond water (no. 5867) is the chief water supply of the Craig Brook station. It is slightly augmented, before reaching the fish ponds, by small volumes of spring water not subjected to analysis. The farm-house spring, whose complete content is not shown, is a minor supply arising on the station grounds, and is probably typical of the springs of the immediate neighborhood, such as the lawn spring (no. 5868) whose content appears in table II. The Craig Brook water itself is in this way shown to contain 1 part of iodine to 1,310,000,000 parts of water; and 1 part of bromine to 149,000,000 parts of water. The farm-house spring showed about the same quantities of each element: of iodine, 1 part to 1,250,000,000; of bromine, 1 part to 142,800,000. The ratio of iodine to bromine was the same in the two sources, 1 to 8.7. As the delicacy of the iodine test detects about one one-hundredth milligram of iodine, the 15-liter sample contained a little more than enough for the reaction.

Since thyroid hyperplasia begins in the Craig Brook water and is reduced by iodine in dilutions which, though much attenuated, are yet much richer in iodine than the above, it seems certain that the extreme dilution of iodine found to occur naturally in the water is without appreciable physiological effect. Most brook water will probably be found to contain iodine in quantities comparable to those in Craig Brook.

Dissolved oxygen.—No lack of dissolved oxygen contributes to the thyroid disease at the Craig Brook station. Flowing brooks almost invariably contain all the oxygen the water will absorb from the air. The Craig Brook water was several times titrated for oxygen and was found to be air-saturated. The water at the outlets of troughs and cement tanks containing trout was likewise examined and the amount of oxygen removed by the fish was determined. A cement tank containing about 40 wild trout diminished the oxygen content by 0.13 cubic centimeter per liter. Sixty-eight yearling trout held in a wooden trough removed 0.4 cubic centimeter of oxygen per liter, leaving an oxygen content of 6.8 cubic centimeters per liter at a water temperature of 15° C., which is barely short of air-saturation.

Spring waters not infrequently emerge from the earth with a considerable deficiency of oxygen. One such was found draining into Craig Brook, holding only 2.39 cubic centimeters per liter at 17.25° C., which is about 35 per cent of air-saturation. Its volume was insignificant, and no additions of this sort to the stream perceptibly affect its oxygenation.

Lack of oxygenation can be excluded from the consideration of causation.

TABLE II.—ANALYSES OF WATERS SUPPLYING CERTAIN FISH CULTURAL STATIONS IN THE UNITED STATES, MADE BY THE UNITED STATES BUREAU OF CHEMISTRY.

[See key below for numbers; these identify the analyses on the records of the Miscellaneous Division of the Bureau of Chemistry.]
 [Figures indicate parts per million. Ft. tr., V. ft. tr., Str. tr. = faint trace, very faint trace, strong trace.]

No. of water sample.....	5865-5866	5867	5868	5874	5875	6594	6597	6598	6709	8742	8743	7976	7977	8744	8755	8126	8127	11737	11738
IONS.																			
Phosphoric acid (PO ₄).....	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Trace.			0.0	0.0		
Metaboric acid (BO ₂).....	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			0.0	0.0		
Arsenic acid (AsO ₄).....	6.2	2.1	9.5	12.7	7.3	9.8	12.4	9.95	10.4	14.9	21.5	21.6	13.3	12.6	13.8	13.6	16.0	7.8	12.1
Silica (SiO ₂).....	6.7	1.0	1.7	2.9	4.9	11.7	9.4	25.2	3.3	4.1	13.9	23.6	21.0	2.9	11.0	8.9	17.4	1.0	3.7
Sulphuric acid (H ₂ SO ₄).....	96.9	12.1	12.1	22.7	36.3	268.1	241.0	28.1	94.5	272.5	372.4	294.8	274.6	137.3	216.6	198.6	270.1	6.4	16.6
Bicarbonic acid (HCO ₃).....	Traces.	2	2	15	3	11.9	5.75	4	.88	.53	.22	3.6	1.0	5.3	7.3	.25	.4	.7	.4
Nitric acid (NO ₃).....	.0025	0.0	0.0	0.0	0.0	0.0	.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Trace.	.0045	0.0	0.0	Trace.
Nitrous acid (NO ₂).....	0.0	0.0	0.0	0.0	0.0	0.0	.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbonic acid (CO ₂).....	4.8	3.6	4.2	2.4	4.4	3.0	2.8	0.0	0.9	2.0	1.3	2.9	0.0	1.3	3.0	Trace.	.5	5.9	5.7
Chlorin (Cl).....	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bromine (Br).....	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iodine (I).....	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Copper (Cu).....	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iron & Aluminium (Fe & Al).....	4	.35	.26	None.	None.	(a)	.56	.91	.1	.28	.37	.5	.3	.4	2.3	.8	.6	.0	.0
Manganese (Mn).....	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calcium (Ca).....	33.0	2.5	3.1	6.4	10.8	58.6	50.3	13.9	17.3	48.1	84.7	65.6	60.6	36.9	39.1	45.3	65.7	2.0	3.5
Magnesium (Mg).....	2.3	1.0	.9	1.3	1.8	24.3	24.1	3.3	9.2	26.5	25.7	30.0	24.8	5.6	23.8	16.5	20.7	.8	1.6
Potassium (K).....	1.9	.9	1.1	.76	.93	2.2	2.0	.95	2.2	1.07	1.49	1.9	1.9	1.1	1.0	.8	1.8	.7	.8
Sodium (Na).....	2.2	3.8	3.7	2.9	3.8	2.0	1.9	1.8	.85	3.49	10.04	4.0	5.1	3.5	3.3	1.6	3.4	5.0	5.2
Lithium (Li).....	0.0	.05	Trace	0.0	0.0	Trace.	Trace.	Trace.	Trace.	.013	.13	Trace.	0.0	Trace.	.04	0.0	0.0	0.0	0.0
Ammonium (NH ₄).....	.015	.048	.032	.01	.03	.01	.02	Trace.	.49	.013	.13	Trace.	.06	Trace.	.04	0.0	0.0	.1	.1
Oxygen (O).....	1.19	.70	.65	.62	.80	1.43	2.83	.98	.49	1.25	3.26	4.25	.88	1.0	1.8	2.44	3.16	1.6	.3
Total.....	155-9575	29.04	37.44	52.08	72.27	393.60	353.414	85.48	140.12	374.733	535.01	452.75	410.14	207.9	323.04	288.794	399.76	32.0	50.0
HYPOTHETICAL FORM OF COMBINATION.																			
Ammonium sulphate (NH ₄) ₂ SO ₄																			
Ammonium nitrate (NH ₄ NO ₃).....	.0442	.142	.095	.03	.99	.03	.06			.04	.39		.16	Trace.	.14			.3	.3
Ammonium chlorid (NH ₄ Cl).....	.30	Trace.																	
Lithium chlorid (LiCl).....	3.63	1.71	2.1	1.45	1.77		3.03		.17	2.04	2.19	3.62		2.1	1.9		1.05	1.3	1.5
Potassium chlorid (KCl).....	5.01	3.97	5.2	2.79	5.77				1.35	1.65		1.94		.5	2.3		8.4	7.9	8.4
Sodium chlorid (NaCl).....	.502	2.81	2.52	4.29	4.38			5.08		6.07	19.95	5.86	14.58	4.0		4.65	10.02	1.5	5.5
Sodium sulphate (Na ₂ SO ₄).....																			
Sodium bicarbonate (NaHCO ₃).....	4.99	2.79	1.31							2.44	12.72								
Sodium nitrate (NaNO ₃).....	.206			.20	.41	7.38	7.01	.55	1.20	.73	.30	4.94	1.37	7.3	9.7	.34	.55	.7	.5
Sodium nitrite (NaNO ₂).....	.0038														Trace.	.007		1.0	.5
Magnesium bicarbonate (Mg(HCO ₃) ₂).....	4.14	6.01	5.41	7.81	7.87	118.49	127.80		54.20	159.45	154.64	150.33	115.00	33.1	125.3	91.87	110.50	4.8	9.6
Magnesium chlorid (MgCl ₂).....						4.00	1.77								.8				
Magnesium carbonate (MgCO ₃).....																			
Magnesium sulphate (MgSO ₄).....	7.97				2.43	14.67	11.78	16.31	.89			24.62	10.93	.3	13.8	5.99	11.41		

^a Copper not determined.^b Copper (Cu) and Zinc (Zn) tested for on one liter.

TABLE II.—ANALYSES OF WATERS SUPPLYING CERTAIN FISH CULTURAL STATIONS IN THE UNITED STATES, MADE BY THE UNITED STATES BUREAU OF CHEMISTRY.—Continued.

No. of water sample.....	5865-5866	5867	5868	5874	5875	6594	6597	6598	6709	8742	8743	7976	7977	8744	8755	8126	8127	11737	11738
HYPOTHEMETICAL FORM OF COMBINATION—contd.																			
Magnesium nitrate (Mg(NO ₃) ₂).....						3.62													
Calcium bicarbonate (Ca(HCO ₃) ₂).....	124.14	4.65	7.38	20.24	39.51	224.96	178.64	37.33	183.05	311.20	225.2	237.51		144.8	149.1	162.08	236.51		10.8
Calcium sulphate (CaSO ₄).....							10.77												
Calcium silicate (CaSiO ₃).....	7.26	4.00	3.69	4.07	2.99	8.63	17.81	4.36	3.20	8.21	22.44	28.73	5.32	5.4	6.4	15.23	20.85	5.8	2.3
Calcium phosphate (Ca ₃ (PO ₄) ₂).....										V. ft. tr.				Ft. tr.	Str. tr.				
Ferric oxide & Alumina (Fe ₂ O ₃ & Al ₂ O ₃).....	.60	.50	.40	.20	1.30	.80	1.3	1.28	.15	.40	.53	.8	.45	.6	3.2	1.15	.90		
Silica (SiO ₂).....	2.45	7.59	10.59	5.75	5.33	5.33	3.16	7.69	8.74	10.65	9.89	6.71	12.54	9.8	10.5	5.70	5.19	5.6	10.9
Potassium sulphate (K ₂ SO ₄).....								2.11	7.70	.76			4.23			1.78	2.78		
Potassium nitrate (KNO ₃).....						5.69	1.06												
Ferrous bicarbonate (Fe(HCO ₃) ₂).....																			
Total.....	155.966	29.08	37.449	52.98	72.27	393.60	353.42	85.48	140.12	374.73	535.01	452.70	410.14	207.9	323.04	288.79	399.76	32.0	50.0
SANITARY EXAMINATION.																			
Ammonia free.....						.01	.02	Ft. tr.	Trace.			Trace.	.06			.0	.0	.10	.05
Ammonia albuminoid.....						.035	.02	.04	.00			.01	.095			.02	.035	.45	.05
Nitrogen as nitrates.....						.000	.004	.00	.00			.00	.00					.00	.016
Nitrogen as nitrates.....						2.7	1.30	.40	.20			3.6	1.00					.15	.44
Oxygen consumed.....						.2	.20	6.75	.15			.3	2.1			.35	.65		

5865-5866, Slocum River, St. Johnsbury, Vt.
 5867, Craig Pond, Hancock County, Me.
 5868, Lawn Spring, Craig Brook Station, Hancock County, Me.
 5874, Artesian well No. 5, Nashua, N. H.
 5875, Coleraine Brook, Nashua, N. H.
 6594, Hatchery Spring, Wytheville, Va.
 6597, Tates Run, Wytheville, Va.
 6598, Hatchery Spring, White Sulphur Springs, W. Va.
 6709, Hatchery Spring, Erwin, Union County, Tenn.
 8742, Spearfish, S. Dak.

8743, Artesian well 106 feet deep, Northville, Mich.
 7976, Spring pond, Northville, Mich.
 7977, Creek, Northville, Mich.
 8744, Spring, Nesho, Mo.
 8755, Middle Spring on Spring Branch, Manchester, Iowa.
 8126, Main Hatchery Spring, Bozeman, Mont.
 8127, Davies Spring, Bozeman, Mont.
 11737, Artesian well, State hatchery, at Cold Spring Harbor, N. Y.
 11738, Nursery pond (spring water), State hatchery, at Cold Spring Harbor, N. Y.

NOTE.—Special determination of iodine and bromine on 15-liter samples from Craig Brook station, summer of 1910. Farmhouse spring water: Iodine, 1 part to 1,250,000.000 of water; bromine, 1 part to 1,420,000.000 of water. Craig Brook water: Iodine, 1 part to 1,310,000.000 of water; bromine, 1 part to 149,000.000 of water. Ratio of iodine to bromine: 1 to 8.7 in each case.

TABLE III.—ENDEMIC GOITER IN CHITRAL VALLEY, INDIA.

Village.	Height in feet.	Pop- ulation.	Per- cent- age goi- trons.	Cretins.	Source of H ₂ O and associated rocks.	Qualitative analysis, grains to gallon.							Remarks.
						Total solids.	Total hard- ness.	Cal- cium.	Mag- nesium.	Iron.	Sul- phates.	Chlo- rides.	
Sanoghar...	7,650	629	41.8	None seen	Snow water from nul- lah, limestone, gneiss, ... do	8.54	5.2	3.6	Present.	Trace.	3	Nil....	Iron can be detected in very concentrated so- lution only. Do.
Miragram...	7,350	275	56.5	One seen, two re- ported. 4	.....do	5.68	3.5	3	Trace...	Trace.	3	Trace.
Awi.....	7,000	426	47		Spring from among limestone rocks.	115.75	35.05	16 and over.	Present marked.	Trace.	3 and over.	Nil....	Iron can be detected in very concentrated so- lution only; much inorganic matter in sus- pension. Iron in concentrated solution only; consid- erable suspended matter and vegetable debris. Village stands on red sandstone; large amount of suspended matter in H ₂ O; iron in con- centrated solution. Considerable amount of suspended matter in H ₂ O; inorganic and vegetable.
Morai	5,753	196	58	3	Snow water from nul- lah, limestone.	45.5	15.75	10	Present.	Trace.	3 or over.	Nil....	
Reohan....	6,480	870	10		Snow water, red sand- stone mainly, and gneiss.	11.375	9.1	3.6	Not found.	Trace.	3	Nil....	
Buni.....	6,860	1,100	15	None seen	Snow water, gneiss, and some limestone.	15.4	7.5	3.6	Trace...	Not found.	3	Nil....	

McCarrison, in his observations (1906) on endemic goiter in India, considers the dissolved content of the waters concerned and is unable to find anything of significance in its relation to the amount of goiter. For the villages of the Chitral Valley, all centers of goiter, he gives the foregoing table (table III). The meager chemical data here shown afford no clue to the explanation of the distribution of goiter in the villages.

He gives similar data for the single water supply of the several component villages known collectively as Gilgit, which are located in a series along the water channel from above downward, so that an increasing pollution occurs toward the lowermost village. There is here an increase of the incidence of goiter from above downward, culminating at the lowermost village. In the following analysis of the Gilgit water supply, the Barmis water is an accessory supply which drains into the main channel. No case of goiter has been found among those who use exclusively this Barmis water.

ANALYSIS OF GILGIT WATERS.

Supply.	Total solids. Parts per 100,000.	Total hardness. Grams to gallon.	Calcium. Grams to gallon.	Magne- sium. Grams to gallon.	Iron. Grams to gallon.	Sul- phates. Grams to gallon.	Chlo- rides. Grams to gallon.	Free. NH ₃ .	Organic matter.	Other metals, lead, copper, zinc.
Gilgit.....	^a 30	7.143	6	Trace.	Trace.	3	Nil.	Nil.	.....	Nil.
Barmis.....	^b 19	9	8-10	Trace.	Trace.	3 or over.	Nil.	Nil.	Nil.	Nil.

^a 21 grams to gallon.

^b 13.3 grams to gallon.

It is thus seen that McCarrison's chemical evidence is negative in its bearing on the origin of goiter. The analyses are far from exhaustive, but it is to be doubted whether greater detail would be more significant. The much more complete data which we show for waters associated with thyroid disease in fishes is as fruitless of any theory of causation.

ENDEMIC OCCURRENCE.

CALEDONIA HATCHERY, N. Y.

Studied from the standpoint of visible tumors, we found that in certain hatcheries the disease is endemic. It is clear that a large proportion of the hatcheries which maintain Salmonidæ under conditions of domestication are more or less affected by thyroid tumors. Studied from the standpoint of visible tumors, the history of the disease in a given hatchery may be traced backward in some cases for several years, although the number of fish observed may be small.

The oldest hatchery in the State of New York is at Caledonia. The water supply of this hatchery comes from springs located about a mile distant from the hatchery. The water supply is unusually ample and there are maintained at this hatchery about 30,000 adult fish. Each year at spawning time approximately 25 to 50 visible tumors are found in handling the fish. This condition has obtained for about 25 years, being within the memory of the present superintendent. The fish are 10,000 rainbow trout and 20,000 brown trout. The brown trout are the offspring of the first importation of

this variety into the United States from Germany in the eighties. They have been continually inbred and no fresh stock has been added. The rainbow trout have been in the hatchery for 25 years and have not had fresh stock added to them. Attempts to maintain the American brook trout in this hatchery have been so unsatisfactory as to have been abandoned of late years. This has been partly due to the prevalence in the waters of the hatchery of a copepod parasite (*Lernæopoda*), which does not affect the brown and rainbow trout, but is very destructive to the brook trout. A few years ago, however, 200 brook trout from the annual hatching were raised to the yearling age for the purpose of exhibition at the State fair. In September, when these fish were $1\frac{1}{2}$ years old, they were examined, and it was found that every individual, with the exception of possibly a dozen, presented visible tumors, and they were for this reason discarded.

It would appear from this observation that the brown and rainbow trout in this hatchery had gradually developed into a more resistant strain than the native brook trout when introduced and maintained under the conditions affecting the hatchery. That this supposition is perhaps correct is shown by the fact that at the Bath hatchery the adult brown and rainbow trout which came from Caledonia remained practically free from the disease during the course of what may be spoken of as an epidemic outbreak in the latter hatchery (p. 77).

CRAIG BROOK STATION: CONDITIONS AT THE BEGINNING OF THE INVESTIGATION.

With the inauguration of a joint investigation by the Gratwick Laboratory and the Bureau of Fisheries, a report of the presence of thyroid disease in the various hatcheries of the Government was obtained, and from among these Craig Brook, Me., was selected for investigation. An examination at this station made by the superintendent between April and May, 1909, disclosed in the 6,695 fish on hand 376 with well-developed tumors. This hatchery has been under the continuous superintendence of Mr. Charles G. Atkins for a period of some 40 years. It is well equipped and at the time of beginning our investigation was particularly suitable for the work owing to the unusual number of salmonoid species kept there and the fact that it was well known as one of the best conducted fish cultural stations in the country. The scientific accuracy of its management and the unusual completeness of Mr. Atkins's records, which extended back over a period of years and covered nearly every factor which the progress of the investigation suggested to us as worthy of study, gave most unusual advantages for accurate analysis of the conditions under which carcinoma of the thyroid had developed here.

An investigation on the ground was undertaken by Dr. Gaylord, covering the months of July, August, and September. A review of the conditions found at Craig Brook during this first summer is contained in an unpublished report transmitted to the Commissioner of Fisheries under date of November, 1909, and was reported during the same month at the meeting of the American Association for Cancer Research.

Our attention was immediately attracted to an arrangement of 19 ponds containing yearling and 2-year-old fish. A careful examination of all the fish in these ponds during the summer revealed the interesting fact that the incidence of the disease increased

from pond to pond where these ponds communicated with each other. Figure 76 shows the arrangement of the ponds, the general distribution of the water supply, the species of the fish, and the incidence of the disease. The following observations on this diagram were made at the time:

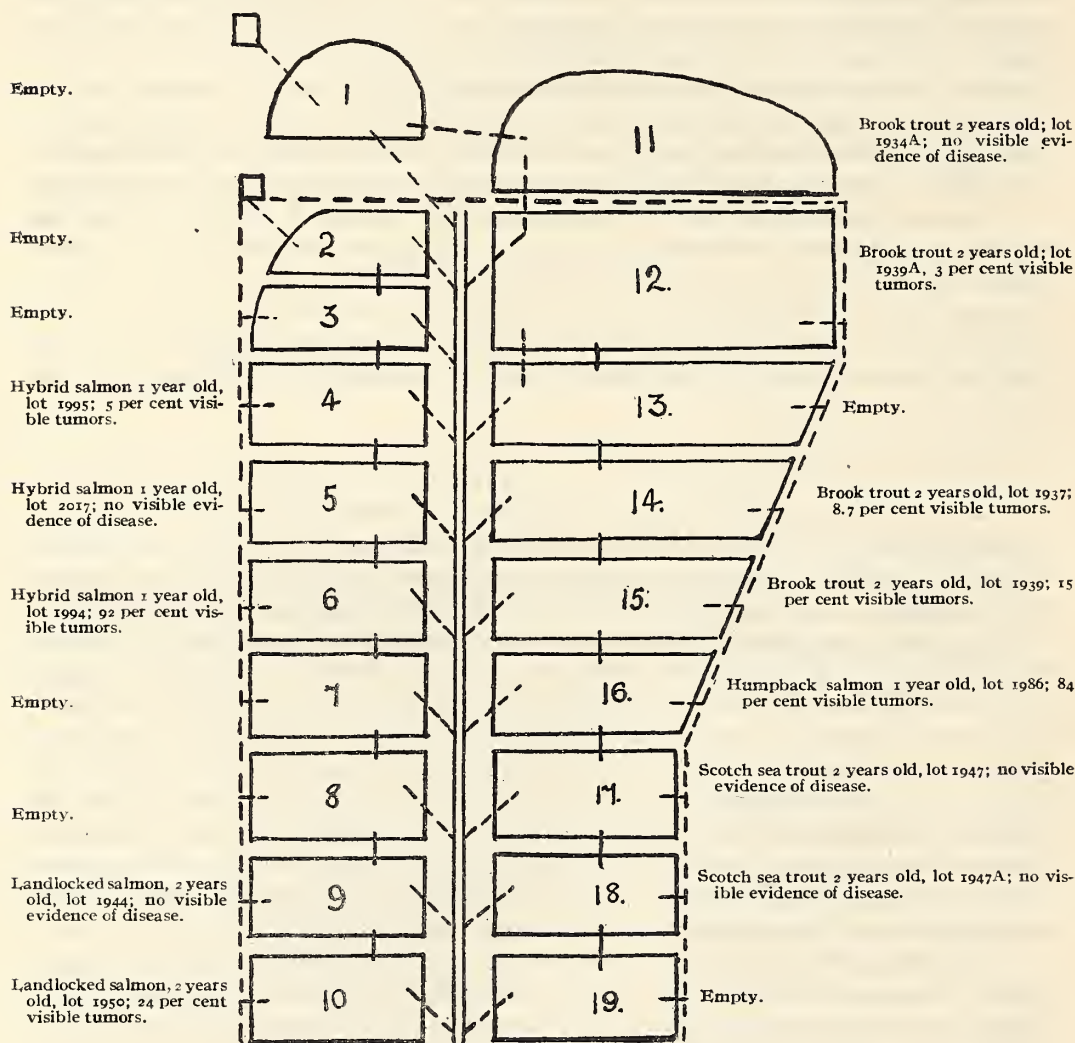


FIG. 76.—Plan of south ponds at Craig Brook station.

The water supply of ponds 1 to 11 is from a natural spring on the hillside. The water supply of ponds 2 to 10 and 12 to 19 is from Craig Brook, the water of each pond for the most part flowing into the pond immediately below it, pond 11 flowing into pond 12. As the diagram shows, pond 11 contained healthy fish. These up to the time of this

observation had not been fed artificial food but had found a sufficient supply of natural food in the grass-lined pond they occupied. Lot 1939 A, 230 two-year-old brook trout, and lot 1939, 132 two-year-old brook trout, were hatched from the same lot of eggs, divided and placed in their respective ponds during the summer of 1908. They were comparable in every respect except their location in the ponds, the feeding for all the lots being the same, i. e., raw liver. Lot 1939 A occupied pond 12 next to the uppermost pond; 1939, pond 15, three ponds below. The chart shows that 1939 A showed 3 per cent of visible tumors, being the lowest incidence of any lot affected, 1939 15 per cent. Between these ponds lot 1937 in pond 14, also 2-year-old brook trout, gave an incidence of 8.7 per cent. Lot 1986, humpback salmon, were yearling fish and in common with the hybrid salmon, lot 1994 of the same age, showed the highest incidence of any of the lots, namely, 84 and 92 per cent. Lot 1950, two-year-old landlocked salmon in pond 10, were the least favorably placed 2-year-old fish and showed the highest incidence for this age, 24 per cent. (Fig. 4b.)

Here we may plainly see that the incidence of the disease increases from above downward in the ponds, both in the 2-year-old and the yearling fish. The deduction may also be drawn from the conditions found in these ponds that the incidence of the disease is greater in the yearling fish than in the 2-year-old, but subsequent observations indicate that other factors, such as the species heredity and hybridization, may so markedly affect the susceptibility that this material is not suitable for such deduction. (See p. 82.)

Perhaps the most striking feature of this diagram is the evidence it affords of immunity in certain species and certain lots. The 2-year-old Scotch sea trout, lots 1947 and 1947 A, were found on examination to present no visible tumors and it was concluded that they were immune to the disease, a fact which microscopic examination and further observation has confirmed. The 2-year-old landlocked salmon, lot 1944, occupying pond 9, although placed below the yearling hybrid lot, 1994, in pond 6, were also free from the disease, although the 2-year-old landlocked salmon, lot 1950, immediately below them in pond 10, showed the highest incidence of the disease in 2-year-old fish. Yearling hybrid salmon, lot 2017, were also free from the disease and in accordance with the general scheme, the smallest incidence in susceptible hybrid salmon, lot 1995 in pond 4, is found in the uppermost pond. The further histories of the hybrid lots and the immune fish are traced in the observations of the succeeding years.

An attempt was made to trace the history of these fish from the time they were hatched in the hatchery through the various troughs which they occupied at different periods up to the time of their final location in these ponds. The records pertaining to the various lots covered the origin of the eggs, the time of hatching, the mortality at every stage of their history in the hatchery, the temperature of the water taken three times daily, and exact data as to the feeding, when first begun, and the amounts fed. While it was impossible to determine the exact troughs in which, or the exact time when, the fish might have contracted the disease, yet our attention was finally fixed upon a

group of wooden troughs which the records showed had been previously occupied by the fish that were now affected in the ponds. In October, 1909, these troughs were occupied by small fish hatched the preceding spring, and from one of the troughs a small brook trout, a so-called fingerling, was found dead and proved on examination to have a protruding visible tumor in the thyroid region. (See fig. 73.) On microscopic examination this was found to be tubulo-alveolar solid carcinoma, infiltrating the surrounding structures. (See fig. 64.)

These, in the main, are the facts which were impressed upon us by the undisturbed conditions at Craig Brook. The observations of the following summers were carried out on a more extensive basis.

CRAIG BROOK STATION: CONDITIONS DURING THREE YEARS.

The Craig Brook fish cultural station (fig. 77) of the United States Bureau of Fisheries is located on Lake Alamoosook about 1 mile from East Orland, Hancock Co., Me. It is but a few feet above tidewater. The station was established in 1879 for the artificial propagation of trout and salmon, though Atlantic salmon eggs were first hatched there in 1871-2. It is well provided with troughs in hatchery buildings for the incubation and hatching of eggs, with troughs out of doors for the rearing of young fish, and with earthen ponds for holding older fish and adults. Craig Pond drains into Lake Alamoosook through Craig Brook, the whole flow of which is intercepted for fish-cultural purposes. A small quantity of spring water is also available for the station supply.

Fish culture at Craig Brook has been chiefly concerned with brook and rainbow trout, the Scotch sea trout, landlocked salmon, and with hybrid trout and hybrids of some Pacific salmon. Investigations of thyroid disease among the fish were first made in 1909, as above stated, and have been continued more or less to date, especially during the summer months. Thyroid carcinoma was immediately found endemic at the station, and affected every salmonoid species or hybrid except the Scotch sea trout, which is almost immune, and the chinook salmon.

The system of outside ponds holding adult fish at Craig Brook station is shown in figure 78 (p. 429), and has been already referred to. A more exact study of the water supply shows that, with two exceptions, these 19 ponds receive brook water and in part discharge into each other from the upper to the lower. Pond 1, however, receives only spring water, which is discharged into pond 11 and thence drains independently of all others. The rest of the ponds are each supplied in part with fresh brook water and in part with this water after it has flowed through preceding ponds in the series. The ponds are entirely of earth and some have small quantities of higher plant life, besides harboring abundant growths of filamentous green algæ during the summer months. Ponds 1 and 11 are best supplied with vegetation. (Fig. 80.)

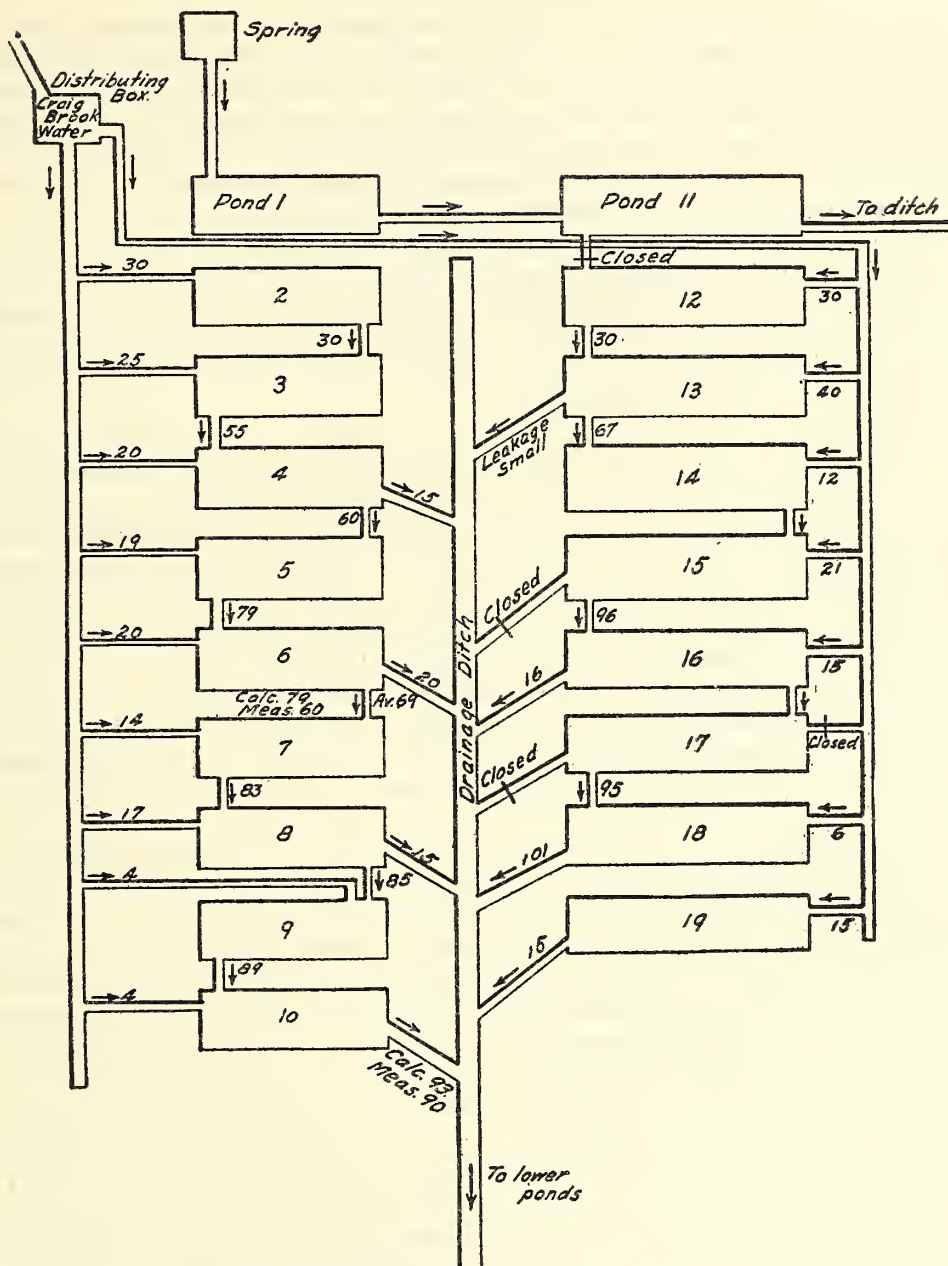


FIG. 78.—Plan of ponds, Craig Brook station, showing water supply.

In this pond system trout and salmon and hybrid trout and salmon, of various adult ages and sizes and of various species, were held under ordinary fish-cultural conditions, varied to a slight extent for experimental purposes, during some three years. Nearly all were examined each summer for four consecutive years. Thyroid disease was seen among them in all degrees of severity up to large visible carcinomata, and with greatly varying incidence from all but complete immunity to macroscopic involvement of more than 90 per cent of the individuals of a given pond lot.

The physical conditions in these ponds were those common to intensive breeding of trout. All the factors of crowding, artificial food, reduced water supply, and accumulation of waste products, as compared with conditions under which trout live in a wild state, were present in greater or less degree. But the reaction of the fish to these conditions, as expressed by the macroscopic evidence of the thyroid disease, was by no means uniform but varied within wide limits.

It is of interest to consider more in detail the external evidence of thyroid growth in these fish over a term of years. The identity of a given lot of fish is preserved by a number. Visibly affected fish are those showing any macroscopic indication of abnormal thyroid growth from the red floor upward. Visible tumors refer to those showing definite tumors. It will be noticed that the loss on the lots from year to year is in most cases considerable. This of course is not to be charged entirely to thyroid disease, either directly or indirectly. Besides intercurrent disease, many fish are lost by depredations of predatory birds and animals, and it is impossible for obvious reasons to apportion the total loss quantitatively among these separate factors.

Table IV summarizes the condition of each lot at the summer examination during three or four years, and gives the percentage of loss. The tumor fish were permanently removed at each examination, unless otherwise stated. The fish with red floors only were not so removed.

In pond 1 were placed, in August, 1909, 119 2-year-old landlocked salmon (1950 T), all bearing visible tumors. They were taken from lot 1950. They were fed proteid artificially until February, 1910, and thereafter received only such food as the pond naturally afforded. A large measure of recovery occurred (p. 87). After one year nearly half the visible tumors had disappeared. The next year only two fish were left and the experiment was abandoned. In August, 1909, 28 2-year-old clinically clean brook trout were present in pond 11, and the annual remnant has remained clean ever since. The conditions in these two ponds, which are separate from the rest of the series, were discussed on page 68. The only water supply of pond 11 came from pond 1, which contained at the beginning only tumored fish, and the fish in pond 11 regularly received artificial food.

Ponds 2, 12, and 19 receive only unused brook water, while nearly all the remaining ones receive the greater part of their supply from the next pond above and the lesser part direct from the brook. Pond 4 had in August, 1909, 146 yearling hybrid salmon, lot 1995 (female humpback and male blueback) with 5 per cent of visible tumors, which were left with the clean fish. The next year there were 9 per cent and the following year none, though the total affected fish had reached 37 per cent.

Pond 5 in August, 1909, contained lot 2017, consisting of 729 yearling hybrids (female brook trout and male landlocked salmon), all clean fish. These were the survivors of 1,553 fish of the previous April, all of which were clean at that time. This lot was almost immune for two years. Only 13 red floors and 2 tumors were produced in one year. The next year all of the remaining fish were clean, and finally in 1912 there were 10 tumored fish among the 220 remaining.

In pond 6 were placed, in August, 1909, 469 yearling chinook salmon. This pond previously contained lot 1994, badly affected hybrid salmon. During the two years in which these chinook salmon were kept under observation no visible thyroid process was produced. This species (*Oncorhynchus tshawytscha*) is a Pacific salmon, an anadromous marine fish. In no adult marine salmon have we seen thyroid disease. Humpback salmon yearlings in troughs of fresh water at the hatchery acquired a heavy tumor involvement.

Ponds 7 and 8 contained in July, 1910, 147 clean yearling rainbow trout (lot 2133). No visible tumors have been produced. After one year 3 per cent had red floors and after two years only 2 fish of the 31 remaining had the incipient process.

Pond 9 held, in August, 1909, 97 clean 2-year-old landlocked salmon. They remained clean during the first year. In July, 1911, there were 10 per cent of red floors, but no visible tumors. In August, 1912, there were but 32 fish left, of which 1 had a red floor and 1 a tumor and red floor.

Pond 10 is the lowermost of the first row of ponds and is almost entirely supplied by previously used water. In August, 1909, the 673 clean, 2-year-old landlocked salmon remaining after the removal of 219 tumored fish from lot 1950 were placed in this pond. The loss was not excessive on this lot. By July, 1911, 7.7 per cent had visible tumors while 37 per cent were affected, the fish having reached 4 years of age. Thus the tumor fish of this lot recovered under more natural conditions in pond 1, while the remainder continued to develop tumors under the intensive conditions of pond 10.

Pond 12 receives 30 gallons per minute of unused brook water only. In August, 1909, 7 tumored fish were removed from the 2-year-old brook trout of lot 1939 A and the 223 clean fish were left in pond 12. In July, 1910, but 80 fish remained, of which 5 per cent were affected, including but one tumor. In 1911, 5 per cent had tumors and 25 per cent were affected. In 1912 the remaining 58 fish had a slight increase in both respects.

Pond 13 contained cyprinoid fish, which do not, so far as observed, acquire thyroid tumors or any notable thyroid changes, and are not considered in the present study. Pond 14 contained in August, 1909, 167 clean 2-year-old brook trout remaining after the removal of 16 tumored fish from lot 1937. During the next year the thyroid process progressed rapidly, 15 per cent acquiring tumors and 31 per cent becoming affected. During the next year there was a very definite regressive process, and during the last year, the fish reaching 5 years of age, there was again a slight progression. Pond 15 had similar susceptible fish, the process continuing slowly at first and then more rapidly.

Ponds 17 and 18 contain Scotch sea trout, which are of especial interest and importance. These ponds receive almost entirely previously used brook water, and the

essential fish cultural factors are among the most pronounced of all the ponds. The immunity of this species is apparently not quite impregnable. One case of supposed small incipient tumor was lost by accident before a proper examination of it could be made. Several fish with definite red floors have been observed, but these are cases of colloid goiter rather than the hyperplastic stages comparable to those of the susceptible species.

At Craig Brook station many unpainted wooden troughs established out of doors are used for holding and rearing young fish until they are large enough to demand transfer to ponds. They are each about 3.1 meters long, by 32 centimeters wide and 23 centimeters deep. (Fig. 79.) They are supplied by brook water, in part from the hatchery building with water which had flowed through the hatchery troughs, and in part freshly from Craig Brook. The water supply of these outside troughs flows from one trough to the other among some of the series of troughs. Troughs 93 to 104, however, shown in table v, receive water immediately from the hatchery. Fish are not usually held in these wooden troughs beyond the first year, but in those of table v they have been continued beyond the third year for experimental results with thyroid disease in these surroundings. The fish were fed the regular artificial food, chiefly liver, and were in general subjected to the usual artificial conditions, the space available and the water supply being less than the earth ponds of table iv would have afforded. This series of troughs was chosen because they were the containers of the young fish which later showed the most visible tumors, and from one of them (no. 92) was obtained the 5-months-old brook trout with a tumor of considerable size, the youngest fish yet found with a visible thyroid tumor. Entirely uniform conditions obtained in these troughs. They were of the same size and shape, supplied by the same water, subject to the same régime, and afford the opportunity for comparable experiments.

It is seen that during these three years the brook trout, landlocked salmon, and various hybrids show progressively increasing thyroid growth from year to year. Fish with visibly affected thyroids not reaching to tumor formation are much more numerous from the beginning than those with visible tumors. The latter often appear among the yearlings, but the chief incidence is among 2 and 3 year olds. The Scotch sea trout are exceptional and show a pronounced resistance here as in the earth ponds. No visible tumors appear during the three years. Out of some 300 fish the second year, 2 only show the incipient hyperemia of the floor of the mouth, and in the third year 1 more. These trout were plainly exposed to exactly the same conditions which result in large percentages of tumor involvement in other species. Their resistance amounts to practical immunity.

In neither the earth ponds nor the wooden troughs are the observations sufficient to establish anything but the general conditions of fish culture or domestication, under which thyroid disease progresses. None of the specific factors of which domestication consists have been or can be isolated in this way. It is plain, nevertheless, that earth ponds are unnecessary to the disease. The wooden troughs are easily kept clean and do not become fouled for long by the accumulation of the products of the fish and

the unused food. The material of the trough, though water-soaked, affords no permanent lodgment for gross particles of organic matter.

Since thyroid carcinoma in fishes is rare in nature and common in domestication it would seem that some or all of the conditions of domestication—artificial propagation of fish—either by their own direct action cause the disease, predispose to it, or carry its cause to the fishes. That domestication itself, viewed as a single complex whole, is *per se* the cause of thyroid disease, is *a priori* highly improbable, and is negatived by the occurrence of thyroid tumors in wild fish. This occurrence, though sporadic and rare, is now established beyond dispute and is a fact of great significance. Domestication predisposes to the disease and carries the causative agent to the fishes, and some one or very few of the constituent factors or conditions of domestication is probably of chief importance in this action. From a study of the conditions at such a station as Craig Brook, while the disease is spontaneous and endemic under the routine of fish culture, it is difficult to fix accurately upon any one of these conditions to the exclusion of others as the prime essential. Feeding is probably more important than any other one factor. The removal of feeding or change to natural food tends toward the recovery of affected fishes, and prevents or delays the initial process. The inevitable reduction in the available unit of water supply per fish and the crowding of fish together in small areas are no doubt factors of next importance. We do not believe that the soluble products of metabolism and of the disintegration of organic matter left from feeding or otherwise play any important part in the origin or progress of this disease, unless as creating more favorable conditions for the development of a causative agent. An unfavorable general hygiene of the fish predisposes to the disease, domestication itself as usually practiced involving a more or less unfavorable hygiene, and in this way these soluble products may enter somewhat into the problem of causation.

TABLE IV.—INCIDENCE OF THYROID CARCINOMA IN DIRT PONDS, CRAIG BROOK, 1909-1912.

[Where there are two entries for August, 1909, under total number of fish, the number before and after removal of tumored fish is indicated.]

Pond No.	Lot No.	Date.	Age.	Species.	Total number fish.	Visibly affected.	Visible tumors.	Loss.
			Years.			Per cent.	Per cent.	Per cent.
1	1950T	Aug., 1909	2	Landlocked salmon	119	100.0	100.0	
		July, 1910	3	do.	39	90.0	56.0	67.0
		July, 1911	4	do.	2	50.0	.0	85.7
4	1995	Aug., 1909	1	Hybrid salmon ^a	146	(?)	5.5	
		July, 1910	2	do.	138	.0	.0	
		July, 1911	3	do.	77	13.0	9.0	44.0
5	2017	Aug., 1909	1	Hybrids ^b	27	37.4	.0	65.0
		July, 1910	2	do.	729	.0	.0	
		July, 1911	3	do.	542	3.0	.3	26.0
4	2027 and 2028B	Aug., 1911	3	do.	415	.0	.0	23.5
		Aug., 1909	1	Chinook salmon	220	5.4	4.5	47.0
		July, 1910	2	do.	469	.0	.0	
7	2133	July, 1910	3	do.	230	.0	.0	50.9
		July, 1911	2	do.	53	.0	.0	76.9
		July, 1911	3	Rainbow trout	77	.0	.0	
8	2133	July, 1910	2	do.	59	3.4	.0	26.0
		July, 1911	3	do.	70	.0	.0	
		July, 1911	4	do.	46	2.2	.0	34.3
7-8	1944	Aug., 1912	2	do.	31	6.4	.0	70.0
		Aug., 1909	2	Landlocked salmon	97	.0	.0	
		July, 1910	3	do.	73	.0	.0	24.7
9	1944	July, 1911	4	do.	66	10.6	.0	9.4
		Aug., 1912	5	do.	32	6.2	3.1	51.0
10	1950	Aug., 1909	2	do.	892	(?)	24.5	
		July, 1910	3	do.	673	.0	.0	
		July, 1911	4	do.	600	13.0	3.0	11.0
11	1934A	Aug., 1909	2	Brook trout	557	37.2	7.7	7.1
		July, 1910	3	do.	65	.0	.0	(?)
		July, 1911	4	do.	28	.0	.0	57.0
12	1939A	Aug., 1912	5	do.	8	.0	.0	71.0
		Aug., 1909	2	do.	230	(?)	3.0	
		July, 1910	3	do.	223	.0	.0	
14	1937	Aug., 1912	4	do.	80	5.0	1.2	64.0
		July, 1911	5	do.	80	25.0	5.0	.0
		Aug., 1912	5	do.	58	26.0	7.0	27.5
15	1939	Aug., 1909	2	do.	183	(?)	8.7	
		July, 1910	3	do.	167	.0	.0	
		July, 1911	4	do.	76	31.5	15.7	54.0
17	1947	Aug., 1912	5	do.	71	16.9	5.6	6.6
		Aug., 1909	2	Scotch sea trout	21	19.0	5.0	70.0
		July, 1910	3	do.	133	(?)	15.0	
18	1947A	Aug., 1912	5	do.	113	.0	.0	
		July, 1911	4	do.	59	6.7	1.7	48.0
		Aug., 1912	5	do.	34	8.8	.0	42.4
18	1947A	Aug., 1909	2	do.	17	23.5	12.0	50.0
		July, 1910	3	do.	113	.0	.0	
		July, 1911	4	do.	15	.0	.0	87.0
18	1947A	Aug., 1912	5	do.	18	16.7	.0	.0
		Aug., 1909	2	do.	13	15.3	.0	27.7
		July, 1910	3	do.	301	.0	.0	
18	1947A	July, 1911	4	do.	188	.0	.0	37.0
		Aug., 1912	5	do.	127	10.0	.8	32.0
		Aug., 1912	5	do.	101	6.0	1.0	20.0

^a Female, humpback; male, blueback.

^b Female, brook trout; male, landlocked salmon.

TABLE V.—INCIDENCE OF THYROID CARCINOMA IN WOODEN TROUGHS, CRAIG BROOK, 1910-1912.

Trough No.	Lot No.	Date.	Age.	Species.	Total fish.	Visibly affected.	Visible tumors.	Loss.
			Years.		Number.	Per cent.	Per cent.	Per cent.
93.....	2034	Aug., 1910	1	Brook trout.....	59	28.0	11.0	.....
		July, 1911	2	.....do.....	35	65.7	20.0	40.7
94.....	2036	Aug., 1910	1	Hybrid trout, ♂ brook, ♂ saibling.....	86	.0	.0	.....
		July, 1911	2	.....do.....	77	26.0	1.3	10.0
		Aug., 1912	3	.....do.....	60	48.3	3.3	22.0
95.....	2081	Aug., 1910	1	Landlocked salmon.....	346	2.5	.6	.....
		July, 1911	2	.....do.....	173	5.2	.6	50.0
		Aug., 1912	3	.....do.....	135	26.6	.7	21.9
96.....	2033	Aug., 1910	1	Brook trout.....	85	11.8	7.1	.....
		July, 1911	2	.....do.....	66	25.7	9.0	22.3
		Aug., 1912	3	.....do.....	62	43.5	19.3	6.6
98.....	2037	Aug., 1910	1	Hybrid trout, saibling brook.....	103	5.8	1.0	.....
		July, 1911	2	.....do.....	39	35.9	2.5	62.1
		Aug., 1912	3	.....do.....	28	50.0	14.0	28.2
99.....	2038	Aug., 1910	1	.....do.....	87	8.0	7.0	.....
		July, 1911	2	.....do.....	23	17.4	13.0	73.5
		Aug., 1912	3	.....do.....	11	54.5	18.0	52.1
100 and 101.	2080	Aug., 1910	1	Scotch sea trout.....	898	.0	.0	.....
		July, 1911	2	.....do.....	332	.6	.0	63.0
		Aug., 1912	3	.....do.....	303	1.0	.0	8.7
102.....	2055B	Aug., 1910	1	Brook trout.....	520	16.0	4.6	.....
		July, 1911	2	.....do.....	60	61.6	38.3	(a)
		Aug., 1912	3	.....do.....	47	91.5	34.0	.....
103.....	2105	Aug., 1910	1	.....do.....	205	.5	.5	.....
		July, 1911	2	.....do.....	95	21.0	3.1	53.1
		Aug., 1912	3	.....do.....	76	43.4	6.6	20.0
104.....	2074	Aug., 1910	1	.....do.....	69	16.0	4.0	.....
		July, 1911	2	.....do.....	64	59.3	9.3	7.1
		Aug., 1912	3	.....do.....	53	70.0	17.0	17.1

a Many fish used in experiments.

LAKE AUBURN HATCHERY, MAINE.

This is a State hatchery in Androscoggin County. In August, 1910, an examination of fish for visible tumors was made and the general conditions inspected. Pond 1 was a dirt pond fed by two springs of water very cold at its origin, and standing at 11° C. in the pond on August 20. The spring water has a very low content of dissolved matter and is said to have about the same analysis as the well-known Poland Springs of Maine. The pond held nearly 400 brook trout of 3½ years of age, which had occupied the pond since the yearling stage. They had been fed raw beef liver until a year old and raw beef heart ever since. The fish were raised from eggs from the local station and from domesticated eggs obtained from Michigan. They were apparently in fine condition, were feeding well, and had suffered but little loss. One hundred and thirty-one of these trout were examined, of which 20.5 per cent showed visibly diseased thyroids and 5.3 per cent of the 131 bore visible tumors.

Pond 2 was a similar dirt pond, fed from six independent springs and sometimes by the overflow of pond 1. Its water was warmer, being 15.5° C. It held 4-year-old brook and brown trout and adult landlocked salmon. A seine haul of fish were examined. Of 66 brook trout, 21.5 per cent had visible tumors and 19.5 per cent red floors; of 15 salmon, 1 had a red floor and 4 had visible tumors; of 36 brown trout all were entirely clean, without external sign of thyroid proliferation. The food was beef heart. There was no marked mortality rate, but there was a heavy loss on spawn taken from the fish of this pond.

Of a large number of yearling landlocked salmon held in a small pond, 102 were examined. Seven fish were affected, three having red floors and four visible tumors.

There is nothing extraordinary about the conditions at Lake Auburn hatchery, which shows rather a typical case of the endemic occurrence of the disease. Here are spring water, dirt ponds, the common proteid foods, liver and heart, and adult fish in excellent condition from the ordinary fish cultural standpoint, and with no unusual mortality rate, but a considerable morbidity in visible thyroid enlargement, with immunity of the brown trout.

At two other State hatcheries similar or greater morbidity has been determined from actual examination, and reports from superintendents of both Federal and State hatcheries indicate the general extent to which these conditions obtain, with some few exceptions, throughout the territory of trout culture in the United States.

PRIVATE HATCHERY IN THE STATE OF WASHINGTON.

At North Yakima, Wash., an interesting and instructive example is afforded of endemic occurrence among young trout at a newly established private hatchery where 30,000 brook trout were held in earth trenches supplied by spring water. The food for the first six months was liver, after that horse meat. The hatchery was started in March. In the following December, before the trout were a year old, thyroid tumors were observed among them, about 1 per cent being affected. The several specimens we have examined show tumors which, relative to the size of the fish, are among the largest we have seen. One of these was 13 millimeters in diameter in a trout 8.5 centimeters in standard length. Microscopically the structure shows solid carcinoma, among the most malignant of our examples.

Rainbow trout of the same age and living under exactly the same conditions at this hatchery are not affected with thyroid tumors. The region in this part of the State is said to show a high percentage of goiter among female children and among calves and other domestic animals. Statistical studies, however, have not been made.

This instance shows an unusual acceleration of the thyroid process. Malignant carcinoma of large size developed in trout under 1 year of age and during the first year of a fish hatchery. Obviously domestication of long duration, either in the individual fish or in the local station where the fish are held, is unnecessary. Something local at this particular fish hatchery seems to be concerned in the unusual result. Certainly the general conditions of trout culture as expressed at the numerous stations where trout are bred do not result in the rapid course of disease here shown. Is there merely a local intensification at this hatchery of the essential cause of the disease?

EPIDEMIC OCCURRENCE.

The hatchery at Bath, N. Y., referred to in the introduction as having first attracted our attention to this condition, was, up to 1907, free from visible tumors. From the accompanying diagram (fig. 81) it will be seen that the water supply of this hatchery comes from a large pond (A) fed by several springs on land adjoining the hatch-

ery, and many larger and smaller springs in the pond itself, and that this supplies the greater portion of the water to the hatchery. This water is supplemented by a large spring B, forming one system of water supply, while the water from springs C and F forms the other, the two systems uniting in race 12. The water coming from the large pond is aerated in fountains K and L. Springs D and E tap a vein running in a northerly direction at a depth of about 15 to 25 feet. The water from these two springs is now used exclusively in the hatchery building for hatching this season's spawn. The large pond A maintained in 1907 an unknown number of fish living under wild conditions, being fish which from time to time were placed in the pond, where they had then shifted for themselves. The pond is grass-grown about the banks, has a plentiful growth upon its bottom, and presents practically an ideal approach to wild conditions. (Fig. 82.)

In 1906 a brown trout approximately 2 years old was found dead at the outlet of the big pond, and on examination presented two well-developed tumors at the junction of the gills. This was the first evidence of the disease which the superintendent had noted. In September, 1907, pond A was emptied, a large portion of the fish in it escaping into the brook. After cleaning the bottom, removing the grass, etc., the pond was stocked with about 6,000 brook trout fry hatched in the hatchery, and systematic feeding with liver was, for the first time, practiced in this pond. From August to October, 1908, a few of the yearling fish in the large pond were found dead with visible tumors. In October the fish in the lower races supplied from the big pond also began to die in sufficient numbers to attract attention, and a large proportion of these were found also to have visible tumors. During the summer of 1908 not less than 3,000 fish, exclusively brook trout, died in this hatchery with visible tumors. During this period of the outbreak some 175 adult rainbows held in one of the lowermost ponds, to which ran the water from the spring running through the races seriously affected, remained free from the disease, with the exception of 1 fish found late in the season. Some 4,000 yearling brown trout from Caledonia remained free from evidence of visible tumors; as did also some 220 four-year-old brown trout from the same source.

During the summer of 1909 epidemic conditions obtained in this hatchery in more aggravated form than in any previous year. The stock fish as well as the fry were fed almost exclusively on beef livers, obtained twice a week from the Buffalo abattoirs. A large proportion of this liver fell to the bottom of the large pond and there decayed. The food not eaten up in the races was brushed out frequently enough to prevent contamination. About 200 pounds of beef livers were fed weekly in the hatchery. A number of times livers were found with large single or multiple abscesses.

The stock fish in the hatchery in 1909 consisted of the following, some lots of which may be recognized as having figured in the occurrences in the hatchery of 1908—125 to 150 rainbows held in concrete race 13; 3,000 two-year-old brown trout from Caledonia in races 22 and 23; 76 older brown trout; and 700 to 750 brook trout of varying size and age. During the course of the summer the rainbow trout retained their relative immunity to the disease, only 7 developing visible tumors during the summer, notwithstanding the position of pond 13, receiving water from both water supplies, all of it running through troughs and concrete tanks above, in which the disease was very active.

The remainder of some 200 five-year-old brown trout referred to in the summer of 1908 as free from tumors were again examined closely and found to be in a healthy condition, showing no visible tumors.

A distinct change, however, was found in the 4,000 brown trout from Caledonia, which in 1908 showed no evidences of visible tumors. This lot is described in 1909 as consisting of about 3,000 fish, now 2 years old, from 6 to 8 inches in length. These occupied cement races 22 and 23. Owing to insufficient help, it was not possible to examine all of these brown trout. However, it was possible to determine that the disease in this lot was now well established. Forty-eight died or were picked out from the lot and found diseased. This does not represent the total number of brown trout affected. Between June and the end of September, among the fish which died from this lot, 43 are recorded as having been examined and all showed visible thyroid tumors.

The brook trout of the hatchery were yearling fish, between 700 and 750 in number, kept in races 10 and 11. A number of them were also kept in race 14 and in the large pond. In race 16, wooden, were 100 brook trout from Cold Spring Harbor hatchery. To these were added 56 wild brook trout from the Old Forge hatchery later in the summer. By the middle of June the epidemic among the brook trout was at its height. These fish were examined a number of times and some of the affected ones were put into the large pond and others into the small pond 15. On June 24 the fish in race 10 were examined and 72 affected fish put into the large pond. About 1 fish in every 3 was found with visible tumors. Race 11 contained 142 yearling brook trout. Thirty affected fish were found in race 11 and placed in pond 15.

The remainder, 112 supposedly healthy fish, were removed to wooden race 18. This race is supplied with the water of springs C and F, and the Cold Spring Harbor trout kept in this water having remained free from the disease it was hoped that by changing the fish from race 11, which did not yet show evidences of visible tumors, they might be saved. On examining these fish in race 18 in September, 107 of the 112 were found to have visible tumors.

During the summer a large number of the brook trout in the large pond died. One hundred and five of these were found to have visible tumors. Early in the spring the large pond which in September, 1907, had been stocked with some 6,000 brook trout fry hatched during that season and in which during the summer of 1908 a few dead yearling fish were found with visible tumors, was again cleaned, the fish being temporarily transferred during this time. Some 200 of these brook trout, now 2 years old, were estimated to have escaped with the overflow into the brook. This stream was protected by a screen at the lower end of the hatchery and such fish as escaped remained in the brook during the summer, here receiving no artificial feeding during this time and enjoying conditions of freedom so far as ample space and lack of crowding were concerned. That a large proportion of these fish were affected with visible tumors was shown by the fact that during the course of the summer 105 died of the lot transferred to the big pond, all showing visible tumors, and to determine to what degree they might have recovered under the new conditions an examination was made on Septem-

ber 11. The stream was therefore seined and 48 fish were caught and examined. Of these 31 were found to have visible tumors, many of large size.

Pond 15 had been the receptacle for affected fish taken from the different troughs, tanks, and ponds. There were approximately 450 fish in this pond; 164 of these are recorded as dying during the course of the summer. At the end of September the remainder, all of which still had visible tumors, were killed; the record states 276 in all.

The conditions for observation at the Bath hatchery during the summer of 1909 were unfavorable owing to lack of records as to the origin of many lots of fish, to inadequate help, preventing frequent examination of the various lots, and to frequent changes of the various lots from pond to pond, due to the exigencies of fish culture. The most important observations made were the marked degree to which the water of the big pond and the tanks it supplied were involved in the epidemic; the striking evidences of immunity in the adult rainbow and brown trout from the Caledonia hatchery; the fact that the yearling brook trout exposed to the disease in pond 11 continued to develop it rapidly although transferred to trough 18, in which nevertheless the Cold Spring Harbor yearling brook trout in trough 16, which was supplied by the same source, springs C and F, remained free from the disease during the summer; and the lack of evidence of spontaneous recovery in the 2-year-old brook trout living under conditions of partial freedom without artificial feeding during the summer in the brook; the high incidence of the disease in the large pond, A, where the flow of water and proportionately great area of the pond produced conditions much more favorable from this standpoint than are usual under conditions of domestication; and the rapidity of involvement of the fish by the disease and the great number affected.

As the main activities of this research were, in 1909, transferred to the Craig Brook station in Maine, no further observations were made at the Bath hatchery during 1910 and 1911, but in the middle of October, 1912, for the purpose of determining what the condition of this hatchery might then be, an inspection, covering one day, was made. No essential changes have been made in the water supply or other arrangements of the hatchery other than those already described. The hatchery now carries a stock of about 3,000 brook trout hatched in the spring of 1911. With the idea that fish hatched from the eggs of wild fish might prove more resistant to the unfavorable conditions in this hatchery, eggs were obtained from the Ontario Fish and Game Commission in Canada. Approximately 1,500 fish were hatched from these eggs and maintained in a separate trough. The remaining 1,500 fish were hatched from eggs obtained from a private hatchery in Massachusetts, and were also kept in a separate pond. Both these lots of fish showed well-developed examples of the disease ranging from the first evidence of red floor to protruding tumors of 7 to 10 millimeters. Of the 1,500 fish hatched from the wild-fish eggs, some 200 were examined, 9 of which were visibly affected, and 200 examined from the lot of 1,500 hatched from the eggs from the Massachusetts hatchery showed 12 diseased fish. From this inspection it is evident that the disease is still endemic at the Bath hatchery.

HYBRIDIZATION.

Hybrids of the brook trout with the American saibling (Sunapee trout) and with the landlocked salmon do not differ materially from the pure species in reaction to thyroid disease. Lot 2017, for instance (female brook and male landlocked salmon), as yearlings showed no visible process, and experienced very little involvement during four years. Lots 2036, 2037, and 2038 (brook plus saibling) were little affected as yearlings, but considerably at three years. The appearance and character of the growth is substantially the same as in the brook trout. These crosses, within the genus *Salvelinus* and the closely related *Salvelinus* plus *Salmo*, are more or less successful, and the fish resulting are hardy, and grow to maturity and reproduce.

The hybrids of the Pacific salmon, though all contained in the same genus (*Oncorhynchus*), are greatly inferior in vigor to their constituent species, and probably could not maintain themselves. They do not do well under fish-cultural conditions, are not hardy, and easily succumb to unfavorable conditions. Hybrids of the silver and humpback salmon are subject from the embryo to deformity of the spinal column in the region of the caudal peduncle. They are readily susceptible to thyroid disease. One of these hybrid lots showed as yearlings the highest incidence of visible tumors yet observed in any large homogeneous brood of fish (p. 67). One lot, however (silver plus humpback, 1988A), consisted at the first examination of but 17 fish, all of which were tumored; and all the Pacific hybrids showed a high percentage of tumors. The general gross appearance of these growths is markedly different from that of the trout tumors. The hybrid tumors have a marked symmetry, most apparent on the floor of the mouth. Here the growth as it vegetates into the mouth usually occupies the median bridge, and spreads equally over the arches so that the right and left halves of the tumor are alike, and a distinct and sometimes almost perfect bilateral symmetry appears. The surface of the growth is unusually smooth. The benign impression which results is belied by the structure, which in these growths in hybrid salmon is among the most malignant of the thyroid tumors in fishes. Likewise the cachexia observed among tumor fishes is most extreme in these fish. (Fig. 4a).

CLINICAL COURSE.

MORBIDITY AND MORTALITY.

There is no very definite symptom picture among the affected fishes. The disease usually runs a slow chronic course. The earliest external evidences may doubtless occur in very young fish only a few months old, but rarely do fish of this age show any outward signs of disease. The beginning of the process is without clinical symptoms until the red floor or an evident tumor appears. The earliest gross tumor we have seen is in a brook trout about 5 months old. (Fig. 72.) Not many tumors are seen until the fish reach the yearling stage, when the growth is usually still small and not causing much interference. In certain hybrid salmon, however, and occasionally in brook trout, the growths in yearling fish have already reached a relatively great size, sometimes almost their maximum. These hybrids die rapidly and do not grow to maturity. In brook

and other pure trout species the tumors grow progressively with the growth of the fish to maturity. At the spawning season gravid fish are often thrown out and destroyed on account of the presence of large thyroid tumors, and doubtless eggs from such fish not infrequently find their way into the hatchery. As far as we know they may be fertilized and hatched like the eggs of other trout.

Only the larger tumors are evident to a casual inspection of the fish. To determine whether a fish has a thyroid tumor it is necessary to examine the thyroid region from all sides after spreading wide the gills and opening the mouth. A considerable proportion of the trout in fish-cultural ponds may have developed visible tumors without the knowledge of the fish culturist. By such an examination 31 per cent of the 2-year-old brook trout at one hatchery were found to have visible thyroid tumors, while 33 per cent showed the red floor indicative of an earlier stage of thyroid disease.

Thus 64 per cent were visibly affected, although the fish culturist knew of the existence of this disease only from having occasionally seen a dead trout with a swollen gill region.

The first obvious effect of the tumor is the mechanical interference with breathing and eating as the tumor grows larger. By filling the mouth it obstructs the passage of food, and by its growth downward and outward it spreads the gill arches, limits their natural movement, and pinches off the vessels until in portions the circulation is stopped. Large tumors often show across their surface a pale atrophied series of nonfunctional gill filaments. Yet the fish succeeds in breathing and eating in spite of a surprising degree of interference.

Tumored trout, like healthy normal trout, ordinarily have the blood sterile to common culture media. This is shown by negative results from numbers of attempts to obtain cultures from the heart blood of freshly killed trout with tumors, and also from tumor trout dead of disease. That tumor trout are more subject to terminal infection than other trout is to be expected and is probably the case, though some meager observations made by us at a State hatchery tend rather to support the contrary view. Terminal blood infection in the living as well as the dead trout has, however, been observed, and of course the tumors are frequently infected. That tumor trout frequently die without showing a general infection, or evidence of intercurrent disease, indicates that the thyroid process itself is fatal in a certain proportion of cases. This intrinsic death rate is probably low, but can not easily be separated from the rate of mortality among tumor fish due to all causes.

Hybridization seems greatly to increase the susceptibility of the salmonoids to the incidence of tumors and to its effect on their bodily economy. In some of these the anemia is readily recognizable by mere inspection, and is so extreme in some individuals that the blood scarcely appears red. A case in point is the lot (no. 1994) of yearling salmon (*Oncorhynchus*) hybrids of the female blueback with the male humpback. In April they numbered 1,043, of which 16.7 per cent had visible tumors. By the following August they had suffered a loss of 57 per cent. Of the 594 remaining 92.5 per cent had visible tumors. These showed distinct emaciation, many of them to an extreme

degree, with the accompanying anemia referred to above. They were constantly succumbing to the disease, and the slightest handling, as during the manipulations incident to transportation, greatly increased the death rate. Before the following summer all were dead. The reaction of the disease in hybrids does not afford a typical clinical picture and is not a criterion from which to infer its virulence or its analogies with other disease processes. Most hybrids are not successful fish-culturally, and the salmon hybrids referred to are especially defective and lacking in vigor.

Restricting morbidity to those showing macroscopic evidence of disease, such as red floors or visible tumors, the morbidity rate is widely variant among the various species and hybrids, and under the various conditions of age and surroundings. Our observations show, for brook trout yearlings, a rate from a minimal one-half of 1 per cent to 28 per cent; for 2-year-olds, 20 per cent to 65 per cent; and for older fish from 5 to 91 per cent. Considering visible tumors only, there appears one-half of 1 per cent to 7 per cent for yearlings, 3 per cent to 38 per cent for 2-year-olds, and 1 per cent to 34 per cent for older fish. Landlocked salmon have shown visible evidence of disease in from 2 per cent to 7 per cent of yearlings, and 5 per cent to 37 per cent of older fish. With rainbow trout our experience is very limited, and we have not seen more than 6 per cent of adults affected.

Hybrids of the brook trout and saibling react much like the brook trout, but hybrids of the brook trout and landlocked salmon seem, from experience with one lot only (no. 2017), to have a considerable degree of immunity, showing no involvement until the second year, and at 4 years only 5 per cent were affected. The salmon hybrids of the genus *Oncorhynchus* usually show extreme susceptibility.

On the other hand, the same hybrid with the sexes reversed (lot 1995, male blueback and female humpback), was much less susceptible. It was held at first under the same conditions, in trough 99, and consisted in April of 312 yearling fish, only 1.2 per cent bearing tumors. In the following August there were 146 fish left, of which 5.5 per cent had tumors. The clean fish were then transferred to pond 4. At 2 years of age there were 77 fish left, of which 13 per cent were affected and 9 per cent had visible tumors. At 3 years of age 27 fish were left, and of these 37 per cent showed red floors without any visible tumors.

The direct and indirect mortality rates can not be stated numerically. The process presumably does not kill, whether directly or indirectly, save in the later stages when the tumor is visible, and the only available data on the loss among fish in any stage of thyroid disease is so complicated with losses from other causes—even causes having nothing to do with disease, that any accurate statement is impossible. The mortality rate is to all appearances not uniform, but varies from a slow fish-culturally unimportant loss to occasional epidemic virulence, as in the active progress of the disease and rapid loss of fish at the State hatchery at Bath, N. Y. Ordinarily and in the common exhibition of the disease the death rate may be said to be low.

In the many studies of the distribution of goiter among human beings none is so striking or apparently so directly comparable to the conditions found in the study of the disease in fish hatcheries, as the observations of McCarrison, 1906, of endemic goiter

in the Chitral and Gilgit Valleys of north India. McCarrison had the opportunity of studying endemic conditions among the inhabitants of the small villages of this remote region. His observations are of particular value because the people in these small States of northern India are remote from commerce, communication is extremely limited, many of the communities are shut off from communication even with their neighbors, and the conditions which he describes represent the development of the disease under almost fixed conditions. In the Chitral Valley he describes a series of villages lying along the left bank of the Chitral River, each village deriving its water supply from the narrow mountainous valleys at the openings in which the villages lie.

The water supply is in all cases derived from the melting of the snows on the hills above. It comes from the nullah at the mouth of which the village stands, and is the only supply of that village. As a rule the water from the melting snows runs down the nullah as a turbulent mountain stream, taking up what matter it may on its way either in solution or suspension; in other cases it percolates into the soil and appears lower down in the form of a spring, as in the case of Awi. In the summer months the water is invariably gray from the presence of fine sediment. There are no real glaciers in the district under observation; the water is snow water rather than glacier water. There are no wells in the village, and, owing to the slope of the ground and the nature of the soil, water does not and can not stagnate.

The incidence of goiter in these villages varies from 10 per cent to 58 per cent and appears to be dependent upon the local conditions of the village and its water supply. As compared with the appearance of the disease in the villages of Chitral, McCarrison had observed in Gilgit a remarkable increase of the incidence of goiter in a series of villages scattered along an irrigation ditch where the incidence of the disease increases from above downward.

Gilgit lies between the parallels of latitude 35° and 37° and meridians of longitude 74° and 75° . It is only, however, with Gilgit proper, the capital of the district, and not with the whole of this district that these observations deal. Gilgit is situated on an alluvial fan on the right bank of the Gilgit River, a tributary of the Indus. This fan is roughly 10 square miles in extent and has a gentle slope from its apex, in the nullah from which it derives its water supply, to the river. On this extensive fan eight villages are situated; collectively these are known as Gilgit. The remarks which I have made as to the climate and people of Chitral apply equally to Gilgit. The valley runs east and west. The height of the fan above sea level is 5,105 feet. Appended is a rough diagrammatic sketch which shows clearly the water supply of the different villages of the Gilgit fan.

The water comes from a single source and is conveyed to the different villages in open kuls or channels. From the diagram it will be observed that there are two main channels, an upper π and a lower (1). The upper channel has no villages on its banks till it joins the lower kul, at the village of Majinpharri, marked (3). All these seven villages are situated on the banks of this lower kul or are supplied by lesser channels branching from it. Each village in this way receives the drainings of the village or villages above it, till at the last village, Kashrote, the drinking water has been polluted by the six villages above.

The water in these open channels not only supplies the inhabitants with drinking water, but it irrigates their extensive crops, serves as an open sewer, is used for the cleansing of their bodies, household utensils, and wearing apparel. It can readily be imagined, therefore, that considerable organic impurities find their way down to the lower villages; yet, being fed as these channels are by a purer supply, little organic impurity can be detected by qualitative tests.

The water is, during the winter months, at its source clear and sparkling, but at the village of Kashrote (see diagrammatic sketch of water supply and plate Gilgit Valley, western end) invariably gray from the presence of fine sediment and impurities from the villages and lands irrigated by it. During the summer months when the snows are melting it is, of course, much worse.

If the sketch of the Gilgit water supply is referred to it will be observed that the Barmis spring joins the supply already described at 3, Majinpharri. This spring does not produce goiter; it is the supply of all the European residents and their servants; there is also a small village on its banks, among the inhabitants of which there is no single case of the disease. It is a very pure water, springs from

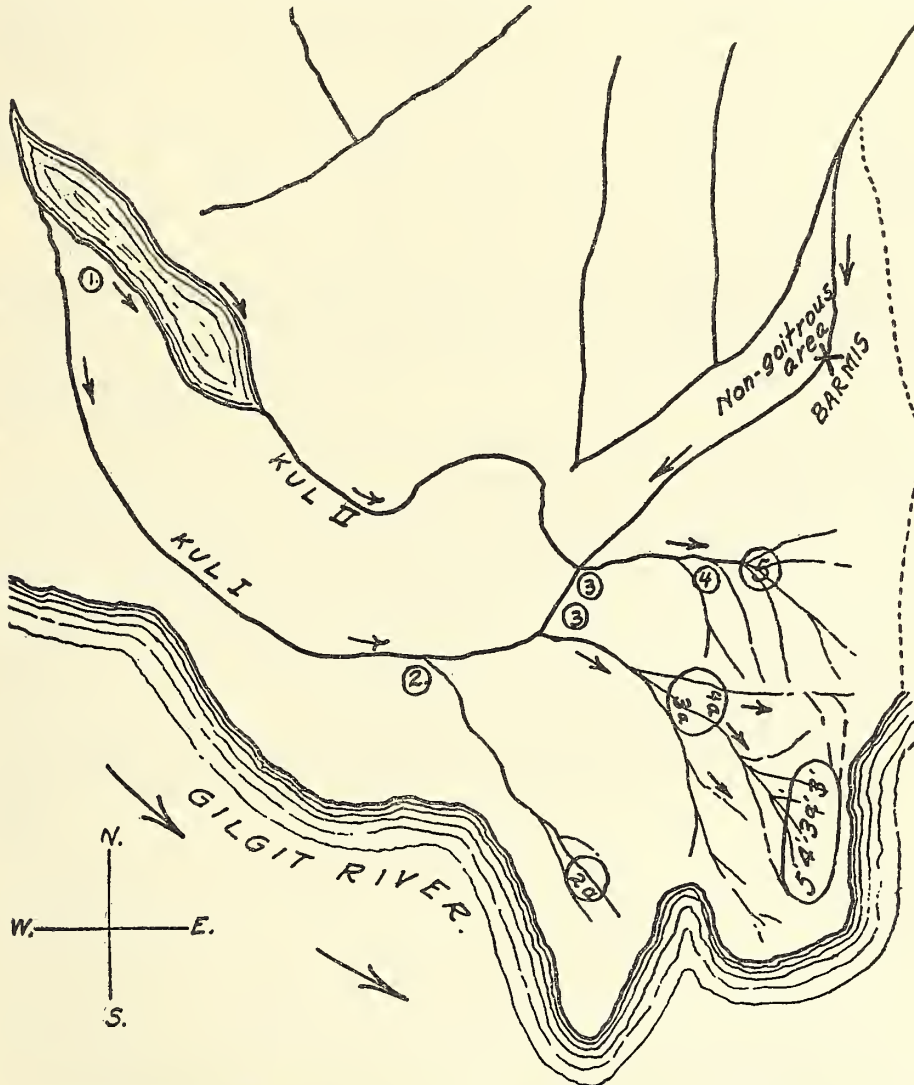


FIG. 83.—Diagrammatic sketch showing water supply of the villages of Gilgit fan, India. After McCarrison.

among rocks, and I have been unable to trace any case of the disease due to the drinking of its water. This is a point of very considerable importance, showing as it does that the other water supply is the vehicle by means of which goiter is produced in the inhabitants of Gilgit. The analysis of this water of Barmis will be found in the table of analyses of Gilgit waters (table III).

In considering the prevalence of goiter in the villages of Gilgit the villages are dealt with in order, from that highest on the water supply to that lowest (see sketch of water supply). The figures are given in the following table:

Village.	Popula- tion.	Houses.	Infected houses.		Persons infected in infected houses.	Total popula- tion goitrous.
	<i>Number.</i>	<i>Number.</i>	<i>Number.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1. Basin	93	35	9	60.0	21.2	11.8
2. Umpharis	385	66	42	63.6	28.3	20.0
3. Danyal	181	30	20	66.6	30.3	18.8
4. Majunpharri	718	108	68	63.2	24.2	20.0
5. 6. Kyk	229	33	23	71.5	30.0	26.9
7. Sonyar	458	63	52	82.5	30.0	24.5
8. Kashrote	128	24	21	87.0	36.0	45.6

It is quite clear that McCarrison has observed conditions which are remarkably comparable to the conditions found in the Craig Brook hatchery where we originally found the increase of the disease from above downward in the ponds, with absence of the disease in the two uppermost ponds fed with individual spring water supply (fig. 78, p. 429); also to the conditions which we have described at Cold Spring Harbor.

The age incidence of visible manifestations of this disease including both red floors and tumors affords material for a comparison of the incidence of the disease as we have observed it in fish and that of goiter in the inhabitants of the villages of Chitral and Gilgit Valleys, as recorded by McCarrison, as well as that of goiter in school children as given by Schittenhelm and Weichardt. McCarrison examined 646 inhabitants of the villages of Chitral, of which 277 were children under 15, and 369 adults. At 5 years of age male children showed 40 per cent, female 22 per cent. The incidence of the disease rises rapidly to 15 years where the males showed 74 per cent, females 59½ per cent. From this age it rapidly fell in both cases so that at 25 years of age males showed 40 per cent, females 24 per cent. From 25 years on, the incidence in females again rose, until the age of 45 when 62 per cent were affected, the males having steadily fallen to 23 per cent at the same age period. In Gilgit the total population examined was 1,533, of which 705 were children under 15 years and 828 adults. The incidence for males and females varies slightly. At 5 years of age 2 per cent of the males and at 15 years of age 16 per cent of the males and 20 per cent of the females were affected. In this locality the incidence steadily rose to 40 years of age when 45 per cent of the males and 36 per cent of the females were affected. McCarrison states that in Chitral 23 per cent of children under 1 year of age who are still being suckled suffer from this disease in the village of Awi, and in another village, Miragram, the percentage figure was even higher than this, reaching 61.5 per cent. The mothers had in all cases been the subject of the disease and frequently the fathers also. What proportion of these cases were congenital and what acquired he was unable to determine.

Schittenhelm and Weichardt state that in a typical goitrous community in Bavaria the incidence of goiter as expressed by demonstrable enlargement of the thyroid is, from 2 to 6 years of age, 42 per cent; 6 to 9, 72.4 per cent; 9 to 13, 89.6 per cent; and

that for recruits who have reached the age for military service for the district, 9.22 per cent. From this it would appear that there is a steady increase of goiter in school children up to the age of puberty, with a marked decrease between that age and 20.

Our tables show that for brook trout yearling fish the maximum is 28 per cent, for 2-year-olds 65 per cent, and for fish older than 2 years 91 per cent. It may be stated for brook trout in captivity that a large proportion of them at least have acquired their reproductive faculties in the second year and that their full reproductive faculties are certainly acquired by the third season. It thus appears from our figures that fish exhibit a very high, probably the highest, incidence in the period from 2 to 5 years, which in the life of a fish carries it well beyond the comparable period in human beings. We have frequently met with instances of actively growing tumors in the oldest fish under observation and the large tumors in old fish have never presented an appearance comparable to colloid goiter. So far as this comparison is admissible it would indicate that the process in the fish in its age incidence is more in accord with McCarrison's observations than the Bavarian statistics just quoted. Both McCarrison's statistics for man in Chitral and Gilgit and our own for fish reach well into the period of increasing incidence of neoplasms in mammals.

HEMOGLOBIN ESTIMATIONS.

In the autumn of 1902, before thyroid carcinoma in fishes had attracted attention in this country, one of us observed, incidental to work upon bacterial infection in trout, an anemic condition among a certain lot of brook trout at a State hatchery at Paris, Mich. These fish were $1\frac{1}{2}$ years old and were part of a lot of several hundred which had been sorted and segregated from the general hatchery stock on account of their undersized and stunted condition. Except for their small size this lot was in fair condition and most of them would have spawned for the first time some weeks subsequent to these observations. Of this selected lot the percentage having tumors was not determined but there were more normal healthy fish than those bearing tumors. Even the tumor fish with anemia showed no particular emaciation or falling off in condition.

Nine apparently healthy fish without tumors were taken at random from this lot and hemoglobin readings obtained. Nineteen tumor fish from the same lot then had their hemoglobin estimated in the same way. The range of the former was from 30 to 43, of the latter from almost nothing to 47, the averages being 37.5 and 21.6, respectively. The readings were made with a Dare hemoglobinometer; those recorded as 8 are arbitrarily overstated, the samples scarcely showing red and registering much below the lowest scale reading. The fish showing the highest reading (47) had only a very small tumor, in the jugular pit. The largest fish of the series (first of the table) showed one of the lowest readings, and had marked blood changes. The tumors were not measured or accurately compared, but the larger usually gave the lowest readings. A marked poikilocytosis accompanied a low blood count for red cells. The normal red cells numbered 256,000 per cubic millimeter, or 416,000 including the atypical reds of extraordinarily small size. The red cells of normal brook trout blood number about 1,000,000 per cubic millimeter.

While tumor fish not infrequently have blood infections, plates made from the heart blood of several of these tumor fish remained sterile, save in one case. The hemoglobin readings and other data for each individual are given in the following table:

TABLE VI.—HEMOGLOBIN ESTIMATIONS ON THE BLOOD OF TROUT AT THE STATE HATCHERY AT PARIS, MICH., IN OCTOBER, 1902.

Sex.	Length.	Hemo- globin. ^a	Sex.	Length.	Hemo- globin. ^b
CLEAN FISH.			TUMOR FISH.		
	Centi- meters.			Centi- meters.	
Male.....	15	41	Male.....	20	12
Do.....	11	38	Do.....	16	25
Female.....	11	36	Do.....	16	43
Do.....	11	30	Do.....	16	43
Do.....	11	43	Do.....	16	29
Do.....	12	38	Do.....	15	28
Do.....	12	39	Female.....	10	8
Do.....	11	41	Do.....	18	8
	12	32	Do.....	17	47
			Do.....	10	19
			Do.....	11	22
				10	19
				11	11
				11	27
				11	8
				11	8
				10	18
				11	8
				11	29

^a Average 37.5.

^b Average 21.6.

SPONTANEOUS RECOVERY.

In the microscopic examination of sections of carcinoma of the thyroid at Craig Brook station during the summer of 1909, we occasionally encountered what appeared to us to be evidences of regression in certain tumors. We therefore were led to look for evidences of spontaneous recovery. To determine whether a change to more favorable conditions on the part of the fish would increase the number of spontaneous recoveries, in the autumn of 1909, 119 fish with visible tumors, mostly of large size, were selected from a lot of landlocked salmon (lot 1950), and placed in pond 1 at Craig Brook station. During the winter of 1909-10 two yearling brook trout with small thyroid tumors visible at the isthmus were held without food in a glass jar in the cold with occasional changes of water. One died after a few weeks with the tumor still visible. During 44 days the tumor of the other fish disappeared entirely, leaving the entire thyroid region without external enlargement. In the early spring of 1910 an examination of the 119 tumor-bearing fish in pond 1 was made to determine to what extent spontaneous recovery might have affected this advanced lot. The conditions in the pond were more favorable than in the pond below. Here the fish received pure water directly from a spring, had access to natural vegetation, and obtained from their surroundings some natural food while they were fed very little artificial food. Thus they were in a large degree removed from fish culture. During a year the loss was 67 per cent and of the remaining fish only 56 per cent showed visible tumors.

Aside from the actually observed subsidence of visible tumors under some abatement of the conditions of domestication, trout taken at random from fish-cultural ponds, with clean thyroid region, show the usual microscopic picture associated with thyroid known to have recovered from tumor formation. The wild trout used in feeding experiments showed numerous examples of this sort. (Fig. 91-92.) That trout can recover under apparently the same conditions under which they acquire the disease, and under which other trout are showing progressive tumors, seems sufficiently attested by our experience.

Recognition of spontaneous recovery is a necessary factor in studying the controls of fish treated with various metals. It is a remarkable fact that in only three or four instances in a total of 46 controls did we find spontaneous recovery under the conditions selected for these experiments. Regression does not appear to occur until after the disease has continued for some time. The best evidence of regression from moderate hyperplasia is found in the wild Wisconsin brook trout with selected feeding, in tanks 1 and 2 containing lots 2146 and 2147. (See table VIII, p. 100.)

In this experiment at the end of one year, fish fed upon raw liver and raw ox heart showed marked hyperplasia, whereas those fed upon various other types of food showed no evidence of hyperplasia. At the end of two years the only lots of fish remaining free from evidence of hyperplasia were those fed upon natural food (i. e., live maggots, fresh water and salt water mussels, etc.), whereas those which had from the beginning been fed upon raw liver or raw ox heart in the various experiments, showed a few individuals with well-developed visible tumors and a large number with well-defined evidences of retrograding hyperplasia. A microscopic examination of various fish from these lots will serve to characterize the changes which indicate regression of the earlier stages of the disease. See 2099, 2101, 2103, 2104, on pages 101 and 102.

Summed up, these changes are the evidences of an increased amount of thyroid tissue indicated by the presence of follicles in regions in which they do not normally occur. The follicles are not closely packed as in active hyperplasia, there is no evidence of hyperemia, there is a well-defined stroma, the stroma often forming trabeculae between the alveoli as wide or often wider than the diameter of the follicles. The follicles themselves show great variety in size, a few larger ones are filled with stainable colloid, but the majority of them are small, of irregular shape and free from colloid or are but partly filled with poorly stainable colloid. The epithelium is flattened, often definitely atrophic, the protoplasm greatly reduced in amount, so that the cells are composed for the great part of their nuclei, which stain homogeneously and deeply. (Fig. 91.) Frequently evidences of there having been more than one layer of epithelium may be found. The greatest changes are in the peripheral regions, which is characteristic of the regression of all neoplasms. The evidence of the previous branching and irregular tubular type of proliferation, which characterizes the growing tumor, are found in atrophic structures of tubular and branching shape, sometimes reduced to a mere cord of cells. (See fig. 92.)

From a survey of such specimens it is clear that an actual disappearance of thyroid tissue must have taken place. In the earlier stages of regression from large tumors

evidences of extensive hemorrhage are found, a characteristic which also distinguishes regression following treatment with metals. In such cases organization of the areas of hemorrhage by connective tissue appears. (Fig. 101.) In the earlier stages of regression the periphery of the tumor will frequently show evidences of round-celled infiltration in the stroma. The scirrhous appearance of advanced tumors which have undergone regression is distinctly characteristic. It will be seen that these changes are distinct from the changes following so-called resolution of hyperplastic thyroid which leads to the stage of colloid goiter, as observed in the Scotch sea trout, where the terminal stage of simple hyperplasia is the large follicles filled with stainable colloid, lined by flattened epithelium. (Fig. 22.) The changes here described as regressive are of the same nature as those encountered in the regression of transplanted or spontaneous carcinoma of the breast in mice. (Gaylord and Clowes, 1906.) The microscopic picture of retrograding large tumors in no way differs from the changes following regression by treatment with iodine, arsenic, or mercury, except that no doubt in the latter instance the changes proceed more rapidly and with less evidence of stroma formation. (Fig. 109.)

IMMUNITY.

Among marine species it has been remarked that the chinook salmon held at the Craig Brook station until 3 years of age were entirely immune to visible thyroid growth. These fish were nevertheless in poor condition, and did not grow and thrive normally. This fish is anadromous, and under natural conditions the young, being hatched in fresh water, soon find their way to sea. Notwithstanding this, they may survive and grow to maturity when held captive in fresh water. It might be inferred that the immunity which resides in marine species of salmonoids, or the protection which the sea affords them—no marine species having been found in the sea with thyroid enlargement—is transmitted through the eggs and continued during a prolonged sojourn in fresh water. But the humpback salmon is likewise a Pacific marine species, and yearlings of this kind produced at Craig Brook are fine examples of thyroid tumors. Of 319 fish (lot 1986) about 1 year old, 14 per cent bore tumors when examined in April. By the following August only 79 fish remained, of which 84.8 per cent had tumors. These resembled the tumors of the Pacific hybrid salmon and showed the same structural evidence of malignancy. Wilkie reported (Gilruth, 1902) a thyroid tumor in a 5-year-old Atlantic salmon in fresh water in the ponds of the Clinton hatchery, New Zealand, and we have seen one example at the Craig Brook hatchery in Maine. It is evident that marine species may develop thyroid carcinoma while resident in fresh water.

The best example of species immunity is afforded by the Scotch sea trout, which at Craig Brook is almost completely immune either to visible or microscopic enlargement. One doubtful case of a distinct tumor is recorded and several of red floors, at 3, 4, and 5 years of age. Doubtless trout of this species can not continue indefinitely without affection under the conditions which produce the disease.

While the Pacific salmon hybrids all show a high susceptibility, other hybrids and the brook trout species exhibit various degrees of susceptibility and immunity to tumor formation. The landlocked salmon is about as susceptible as the brook trout, but lot

1944 showed no visible evidence of thyroid disease until the fourth year, though living under the conditions which produced the disease. Lot 2017, hybrids of the brook trout and landlocked salmon, when it consisted of 1,553 yearling fish, showed not a single fish with a visible process. In the second and fourth years a few visible growths appeared. A lot (2133) of rainbow trout, which develops frequent and large tumors at some hatcheries, were held two years at the Craig Brook station without acquiring any visible tumors and only a small percentage of red floors.

As previously referred to, rainbow trout at the Caledonia hatchery in New York appeared to have a very low incidence of the disease, about one-half of 1 per cent of the fish each year showing well-developed tumors, this covering a period of approximately 25 years. As stated, no fresh blood during that period was added to this lot of fish. Tumor fish found each year were destroyed and a probable original resistance of the lot was protected and perhaps added to by this form of selection, so that, as we have pointed out, in the epidemic at the Bath fish hatchery covering a period of two years these fish remained practically immune, only 1 or 2 fish in a lot of 75 adult fish being found with tumors in the course of the two years' epidemic. Exactly the same state of affairs existed in a lot of 20,000 German brown trout which had also been held without the addition of fresh blood at the Caledonia hatchery. These were represented among others by some 200 of their offspring, which as 4 and 5 year old fish went through the epidemic without a single tumor. This was not the case with some 4,000 young German brown trout which were sent from the Caledonia hatchery to the Bath hatchery as young fish, and which toward the end of the epidemic, as 2-year-old fish, developed a considerable incidence of the disease.

That the rainbow and brown trout retained so many years at the Caledonia hatchery really possessed a definite immunity against the disease is shown by the fact that during this time attempts to rear brook trout to adult age and maintain them resulted in a high incidence of thyroid tumors in this species. That a given lot of fish from one hatch may possess at a certain age an almost complete resistance to the disease, while another lot from another hatch of the same species and of the same age, kept under the same conditions, may show a high incidence of the disease, is possibly explainable on the basis of blood relationship. The manner in which spawn and eggs are taken and fertilized would easily bring about the presence in any given lot of a large number of fish with the same parents. With the exception possibly of the hybrids, some of the lots of which were small, no lot of fish which we have studied could possibly be entirely of the same parentage; but as a large number of individuals in each lot are certainly of the same parentage it is explainable that the high degree of immunity or susceptibility in a given lot may be due to this fact. Such a supposition is in accord with the now well-known facts of family predisposition in both goiter and cancer in human beings.

The fish offer a remarkable opportunity for the careful study of this phase of immunity. It will be easily possible to obtain in any hatchery in which the disease is endemic, on the one hand from parents both having visible tumors, or, on the other, from parents showing distinct immunity, a sufficient number of eggs to hatch several hundred fish. A number of fish could be reared from such lots sufficient to demon-

strate clearly in a few generations the exact importance of blood relationship to susceptibility and immunity. To guard against possible accidents obviously a series of such experiments should be carried on at the same time and to this purpose it would be necessary to devote the entire activities of a fish-cultural station for a period of years.

The importance of such an investigation to the question of immunity in goiter and cancer would certainly justify such an undertaking, aside from the possibility of practical results to fish culture. Only in this way can the importance of inbreeding as practiced in fish culture in the production of a general susceptibility among domesticated fish to this disease be properly determined. It is a common assumption that hatchery fish are more or less inbred. We have emphasized this idea in our earlier statements. A marked susceptibility of at least one lot of pure marine salmon species, i. e., the humpback, and in fact the occasional occurrence of the disease in wild fish, indicate that inbreeding as such, except by the perpetuation and accentuation of such susceptibility, may not be considered an important factor and the facts developed in connection with the rainbow and brown trout at Caledonia clearly show that fish-cultural inbreeding may finally develop a markedly resistant strain.

To what extent spontaneous recovery from the disease results in acquired immunity is not easy to state. There are many facts in this investigation which indicate strongly that recovered fish remain immune for a considerable period of time if not indefinitely. An experiment to determine definitely this question, although carried out with too few individuals, failed to realize the development of visible tumors in recovered fish at the end of one year, although placed in one of the lowermost ponds where the incidence of the disease continued to be high.

McCarrison (1906), in his study of endemic goiter in the Chitral and Gilgit Valleys, gives striking examples of family predisposition to goiter and refers to the frequent occurrence of goiter in nursing children where the mother has the disease. Schittenhelm and Weichardt (1912), in their recent monograph on endemic goiter in Bavaria, state that it is easy to trace family predisposition to goiter and append family trees of some 13 families, from which it may be readily seen that certain families show a remarkable incidence of the disease, which is especially marked in children where one or both parents, and especially when both parents and grandparents, are affected by goiter. There are several experimental studies in the lower animals indicating family susceptibility to cancer, the most striking being the breeding experiments of Dr. Maud Slye (1913), and recent statistics emphasize the well-known fact of family predisposition to cancer in human beings. Racial immunity to cancer has been shown by Levin (1910) to be very marked in the American Indians. This fact applies to isolated tribes of Indians living upon reservations extending from the northern to the southern limits of the United States, where the Indians for a period of 20 years have shown almost complete immunity to cancer, whereas the whites living in the immediate neighborhood show the usual incidence of cancer characteristic of the white inhabitants of the country. That such immunity is a special immunity to cancer and not a general resistance to disease is indicated by the fact that the same tribes of Indians show an unusually high mortality from tuberculosis.

EXPERIMENTAL PRODUCTION OF THE DISEASE.

TROUT TUMOR MATERIAL IN STANDING WATER.

The contents of a thyroid tumor of a trout were expressed into tap water and brook trout fry in the sac stage were introduced. About 300 fry were used, distributed in 15 shallow open dishes each with from 1 to 2 liters of the contaminated water. Eighty-five fry in similar dishes constituted the control. By keeping the dishes in the cold the fry were maintained for 23 days without change of water, or other than spontaneous surface aeration. During this period a loss of 16 per cent occurred on the fish in the tumor water and 11.7 per cent on the controls.

After removal from the tumor water the fry and their controls were held for several weeks in flowing tap water and suffered a gradual mortality. Sections of the thyroid region of these fish show no recognizable difference between the controls and those fed the thyroid material. Figure 13 shows the thyroid of a control fish soon after the food sac had been absorbed.

FEEDING TROUT THYROID TUMOR.

Fourteen brook trout of yearling age but of small size, reared almost entirely on live fish food, were fed nine times during one month with portions of fresh thyroid trout tumor. The fish were held for 54 days in glass jars, containing each 3 liters of water and two individuals. The water was changed once during this period. The temperature ranged from a little above the freezing point to 17° C., which made necessary their removal to flowing water. They had received no other food than tumor material. When transferred there was no external evidence of thyroid enlargement. No histological changes in the thyroid tissue were recognized after careful comparisons with the controls.

FEEDING HUMAN CANCER LIVER.

Under the same general conditions as in the preceding experiment 12 trout were fed five times during 23 days with solid human cancer material from metastatic foci in liver of gastric carcinoma. After 54 days they were transferred to flowing water. All were without externally visible thyroid change and showed microscopically the same early hyperplastic stage as the controls.

CLOSED CIRCULATION.

In order to experiment further with normal and tumored trout in unchanged water, two independent aquarium systems were established for using the same water over again continuously by means of circulation, aeration, and filtration. Refrigeration was also provided so that the water could be at all times kept at a suitable temperature for trout.

During 51 days, 16 domesticated brook trout were fed human cancer of the liver on 14 different days, and became reduced to 8 fish in number. The thyroids of 4 of these were affected and 2 had visible tumors, but an accident prevented the controls from covering an equal period, and though the latter, 12 in number, were all clean but one, nothing conclusive is to be inferred.

Fifty clean domesticated yearling brook trout were placed in the closed circulation with several badly tumored trout. In over four months, during a large part of which the water was aerated artificially, without circulation, we did not succeed in producing any notable thyroid reaction, and none which went beyond the controls. We do not believe tumors can be produced by contact or association with tumored fish in this way, at least not in any reasonable time. (See also feeding experiments p. 100.).

The experiments in the closed circulation add to those in standing water in glass dishes in showing that the pollution of the water by the fishes themselves and their food refuse plays little if any part in the thyroid reaction. A number of trout were held for 113 days in a 63-gallon aquarium tank with only four changes of water. Artificial aeration was maintained by a constant air current liberated in minute bubbles at the bottom of the tank. The fish were domesticated yearling trout, but not of a readily susceptible lot, and none of them showed any external sign of thyroid change at the end of the experiment. The fish were fed on liver, ate heartily, and were in good condition throughout the period.

Most brook trout, however, held in troughs at the laboratory and supplied with Lake Erie water tended to acquire the red floor of the mouth when fed on liver. Such trout kept in the ice-cold tap water in the winter and fed nothing, or given very low feeding, showed within a few weeks signs of thyroid regression. Further evidence of such regression is afforded by a yearling brook trout with a small but distinct thyroid tumor visible at the isthmus. It was placed in a glass jar with standing water in the cold and kept for 44 days without food. The water was changed several times. The tumor had completely disappeared at the end of this period.

TRANSPLANTATION AND INOCULATION EXPERIMENTS.

Several attempts to secure a new autonomous growth by implanting portions of visible thyroid tumors in normal trout have been made. Both wild and domesticated trout have been used. In only one fish have we met with partial success in that the graft showed evidence of proliferation and was still alive at the end of three months when examined microscopically.

In December, 1908, a number of supposedly healthy fish were sent to Buffalo from St. Johnsbury, Vt. These were inoculated in the thyroid region with a suspension of thyroid tumors from fish obtained from Bath. The surface of the tumor was carefully sterilized by burning. The greatest precautions were taken to prevent contamination. The center of the soft tumor was carefully scraped out, rubbed up with salt solution, and then injected. Nineteen fish were thus inoculated and later transferred to the Bath hatchery, where they were kept in the troughs of the fish-hatchery building. An examination of these fish in the autumn of 1909 showed that all of them had visible tumors, but the epidemic of 1909 was at that time in full swing, and it was impossible to determine whether the development of tumors was due to the inoculation or to the simple fact that these fish had been placed in the infected water of the Bath fish hatchery.

In a series of fish inoculated at Bath in the summer of 1909, in most of which the grafts were contaminated and sloughed out, one fish (no. 83), which was inoculated Sep-

tember 1, 1909, and killed for examination November 24, 1909, showed at the point of inoculation, which was in the muscular structure of the abdominal wall, just anterior to the left ventral fin, evidence of a small protruding growth the size of a grain of rice. On sectioning this tissue, a slender growth is found extending in what must have been the track of the needle. Under the microscope the growth is made up of a series of nodules, most of them with a not very well-defined connective tissue capsule. The continuity of the epidermis at the point of the small tumor is broken, and we have here a growth of tissue connected with the nodular growths in the deeper structures. This protrudes through the broken continuity of the epidermis. The circumscribed nodules lying between the muscle bundles and the subcutaneous tissue are made up of large spindle and irregularly shaped cells. The centers of the larger nodules contain a certain amount of hyaline detritus. Scattered between the cells of the nodules, particularly toward the center, are many leucocytes. At the outer margins of the nodules the cells are best preserved. The nuclei vary greatly in size, the protoplasm stains, the cell boundaries are not always well defined. The growth is made up of a complex of cells with large vesicular nuclei containing one or more nucleoli. They may be recognized as thyroid epithelium. In a nodule which fills the break in continuity in the epidermis there is a distinct suggestion of tubular arrangement with a definite stroma carrying blood vessels, and at the margin of one or two of the other nodules definite alveoli may be made out.

Toward the centers of the nodules there is distinct evidence of atrophy of the cells, associated with clumps of chromatin and hyaline detritus. There are many cells with very large nuclei. There is generally a great difference in the size and shape of the nuclei. Rarely a karyokinetic figure is found. The cells are closely packed together, but in some nodules there has evidently been a growth of capillaries in attempts at formation of a stroma. From the microscopic picture it is evident that there has been some proliferation in the implanted tissue, and that three months after portions of the graft at least are still alive.

At Craig Brook station in 1910 implants were made directly into the thyroid region of the fish with the aid of a hypodermic needle. It was found that the trout will endure a needle puncture in the floor of the mouth and the injection of one-fifth cubic centimeter of physiological salt solution directly into the tissues containing the thyroid with little reaction. By inserting the needle a little to one side of the median line the ventral aorta is avoided, and most of them show no external bleeding. Some of the fish suffer from shock, due to the puncture, from which they recover within 5 to 20 seconds. Even those which bleed usually do not succumb. Of 76 yearling domesticated trout thus inoculated as controls, only 1 died as a result of the manipulation. The fish tumor material for inoculation was ground up and mixed with its own volume of physiological salt solution. The difficulty in planting this material in the tissues of the trout lies in the high toxicity of the tumor extract. It is not practicable to place transplants of ordinary size in this vascular region without heavy loss from toxemia. The tumor material varies considerably in toxicity. Domesticated trout endure the mechanical injury incidental to inoculation better than wild trout.

Of 30 wild trout injected in the thyroid region with 2 minims each of tumor ground with an equal volume of salt solution, about half died from the immediate toxic effect of the injection. At another trial one-tenth cubic centimeter of material made from several tumors was injected into each of 15 domesticated trout. Eleven of them succumbed almost immediately. The material was then diluted until it contained 3 volumes of salt solution and 15 more fish were injected, but 12 of these died within 2 or 3 hours. Seven fish were injected subcutaneously near the dorsal fin with one-fifth cubic centimeter of this material, and 5 died within a short time. One cubic centimeter was, however, passed into the stomach of 1 trout, and one-half cubic centimeter each into the stomachs of 3 others without apparent effect. This particular sample of combined tumor substance was unusually toxic.

The trout dying from the immediate physiological effect of trout tumor substance ground with salt solution showed a fairly characteristic picture of symptoms, ending in tetany. The mechanical effect is little, as shown by the control fish. In the few cases where the shock from trauma is apparent the fish lies on its back or side, scarcely breathing, and recovers in a few seconds. The inoculated fish, however, were evidently poisoned. They became immediately distressed, swam in circles or in short, frantic, and aimless dashes about the trough, then fell greatly weakened upon their sides and lay there with short and rapid breathing until the next paroxysm. Finally they succumbed in tetany, some with gills widely distended and marked opisthotonos. Even the survivors seemed to be much weakened.

Forty-three wild brook trout were inoculated in the thyroid region with small portions of tumor taken directly from the fish without grinding or mixing with salt solution. Pieces were forced through the floor of the mouth by means of trochar, probe, or seeker. The material was more or less toxic even in this form, and the mechanical injury and bleeding were greater than with the needle, but 24 of the 43 trout survived.

Ten domesticated brook trout were injected in the thyroid region with one-fifth of a cubic centimeter each of a mixture of one volume of domesticated brook trout blood and three volumes of physiological solution. No loss attended the operation, and the fish have never shown any but the immediate reaction to the inoculation.

In all injections and inoculations the instruments used were sterile, and the tumor material obtained as free from contamination as possible. It is not usually possible to obtain in quantity the thyroid tumor material from fish in a completely aseptic condition.

Mud from one of the fish ponds (no. 10) constantly associated with tumor fish was injected into the stomachs of 25 domesticated trout and of 20 wild trout. The dose was repeated on the former lot after three days. The filtrate of this mud through paper was injected into the thyroid region of 25 domesticated trout and behind the eyeball of 17 domesticated trout. The dose was 2 to 2½ minims. These fish have shown no results from the inoculations.

Trout tumor material has been ground with sand and filtered through a Berkfeld filter. The filtrate has been injected into the thyroid region of 2-year-old domesticated trout, all manipulations being carried on in the cold. About 0.3 to 0.4 cubic centimeter of filtrate was given each of 9 trout. These were kept under observation for over four

months, when one thyroid tumor and two red floors had developed among them. The controls had been previously lost from some unknown cause, leaving the result negative.

EXPERIMENTAL INDUCTION OF CARCINOMA.^a

In June, 1910, about 2,400 wild brook trout of various sizes were collected in the wilderness of Wisconsin by the Bureau of Fisheries and brought to Craig Brook station. They were held in Craig Brook above all fish cultural operations until used in experiments. Several specimens were sectioned from time to time and found to be entirely normal. A series of 16 new cement tanks, 2.7 by 1 by 1 meters in size, which had not previously held fish, were used as containers for the experimental lots. (Fig. 79 left.) The depth of water in these tanks was 0.8 meter and the inflow 50 to 60 liters per minute. In July, 1910, 11 lots each of 50 adult wild trout from Wisconsin were placed in 11 of these tanks and feeding experiments begun with a variety of foods, which were maintained for each lot throughout the experiment without change. The so-called natural food was not all of one kind, but consisted of fresh-water mussels, fresh-water fish, and in the summer maggots of flies. The vegetable food was screenings from miscellaneous grains. In September, 1910, certain of the lots were augmented by smaller wild trout from Wisconsin, which had received food corresponding to the lots to which they were added, or natural food.

Table VIII summarizes these feeding experiments and includes some smaller lots which were inoculated in various ways, and were fed natural food. Such lots were negative, and are in effect controls to the feeding experiments. The inoculated lots are discussed under a separate heading. Lot 2149 was an attempt to crowd the fish by confining them in one-third of the tank. Lot 2155 aimed at excess feeding.

Lots 2150 and 2151 were practically wiped out by the unsuitable food, to which the wild trout could not adapt themselves readily. The wild trout gradually became accustomed to the fish cultural foods, liver and heart, and finally thrived upon them about as domesticated trout do. On examination after four months, and again after one year, all the fish were clinically clean, without any external evidence of thyroid disease. At the examination after one year the thyroid region of from one to three fish from each tank was prepared for microscopic study, and the histology of each is shown below by a description of each section by number (table VIII). The diagnoses may be briefly summarized as follows:

In the lots fed raw liver (fig. 84) and heart (fig. 85) a general hyperplasia existed with early carcinoma in a few cases; the two fish from lot 2155 were exceptional, appearing normal. The lot fed cooked liver had remained normal. (Fig. 87.) Those fed marine fish (fig. 88), vegetable food (fig. 89), and natural food (fig. 86) were entirely without hyperplasia. Nearly all remained normal, but a few showed a considerable

^a We believe that these experiments, reported at the fifth annual meeting of the American Association for Cancer Research, April 3 and 4, 1912, in Philadelphia, and reported in the *Zeitschrift für Krebsforschung*, Band 12, Heft 2, 1912, p. 436, under the title, "Relation of Feeding to Thyroid Hyperplasia in the Salmonidae," by H. R. Gaylord and M. C. Marsh, Buffalo, constitute the first instance in which spontaneous cancer has been experimentally induced under properly controlled conditions in the lower animals. They antedate the recent experiments of Fibiger in the production of carcinoma of the stomach and esophagus in rats by feeding them nematodes from cockroaches, for which a similar claim has been made.

increase in the number of thyroid follicles without elevation of epithelium or other changes from the normal. Lot 2163 was exceptional in that two of three fish showed beginning hyperplasia. They had been inoculated with trout tumor material in the thyroid region, the implant failing to take.

At the examination of June, 1912, two years after the beginning of the experiment, one distinct thyroid tumor (fig. 90) had developed in lot 2146 under the feeding of raw heart muscle. This fish, and one lot 2147, which was fed raw liver and had developed a red floor, with slight swelling, showed typical thyroid carcinoma. Of the rest many had developed red floors, as shown in table VIII. One or more specimens were preserved from each lot, and a description of the histology of the thyroid is given below. The trout fed with marine fish, vegetable, and natural food still remained normal, while carcinoma has definitely developed in two of the sample fish fed raw animal food. Those fed cooked liver have passed through hyperplasia to regression and, in fact, the chief characteristic of the microscopic picture in all the fish on meat diet is the regression indicative of spontaneous recovery. (Fig. 91-92.)

In general, it may be stated that the results obtained by selected feeding are in accord with our experiences in the study of hatchery conditions and that the relation of foodstuffs to the incidence of the disease is contributory and not causative. Thus raw liver and raw ox heart used as a food act as a predisposing factor in the development of carcinoma of the thyroid. Cooking the same food tends to delay the advent of the disease and fish fed upon natural food, marine fish, and vegetable food are able to resist the disease for a considerable period of time, if not indefinitely. One might conclude from these experiments that raw liver and raw heart muscle were the sole cause of the disease, were it not for the fact that we are able to check this observation by an observation made at another hatchery where the conditions are practically reversed. In this hatchery all of the fish are fed upon raw liver and raw ox heart muscle; but the fish kept in one water supply are free from the disease with this type of feeding, whereas those kept in other tanks with a slightly different water supply are uniformly affected by the disease. This state of affairs exists at Cold Spring Harbor, N. Y. The hatchery building is supplied with water from an artesian pipe driven near the building. The overflow from the hatchery, and, of course, from the artesian supply, which is not required for the hatchery building, flow into a series of large earth ponds, and then a series of concrete-lined ponds. The arrangement of the concrete ponds is such that one pond is practically continuous, each division for fish being separated from the one above it by an arrangement of boards over which the water flows. The ponds and concrete tanks are old and at the time of examination were lined with a visible growth of green algae.

Young fish hatched in the hatchery in the artesian water were placed for the most part in the concrete tanks just mentioned, but in a few instances the lots were divided and approximately half were placed in a spring located a distance of several hundred yards from the hatchery building. This spring flowed out from a hillside obviously from the same general supply as the artesian water and the springs near the hatchery.

In the small brook about 100 yards in length wooden divisions and tank-like arrangements had been constructed. In these the young fish were placed and all the fish both in the old concrete tanks and in the spring were fed with chopped raw beef liver and ox heart muscle. An examination of specimens taken from the two sources in the autumn of 1911, of fish respectively 6 and 18 months old, taken from both sources, showed that whereas the fish in the old concrete ponds had well-defined hyperplasia (fig. 93), those kept in the spring water had thyroids exactly like those found in wild fish (fig. 94), although both had been liberally fed upon raw liver and ox heart. From this observation we must conclude that the selective feeding experiments at Craig Brook station indicate that the feeding of raw ox heart and liver produce conditions either in the tanks or in the fish themselves which favor the development of the disease, but that such feeding of raw heart muscle and liver is not the direct cause of the disease. It is hard to understand why fish fed upon cooked liver should have resisted the disease so much longer than those fed upon the uncooked liver, unless it is possible that the agent causing the disease is sometimes or usually transmitted with the uncooked materials, or that cooking the material delays decomposition and thus favors a more hygienic condition in the tanks. The complete resistance of fish fed upon natural food, chopped marine fish, and vegetable food, all of which were obtained from sources entirely different from either the heart muscle or liver, would rather suggest that these sources of food are free from the possible contamination with the agent of the disease; or, again, that they are not so easily decomposed in the tanks and do not therefore contribute to a favorable condition for the propagation or development of the agent in the tanks.

McCarrison (1906) points out that in Chitral where goiter is endemic the people are for the most part poor. Food is plentiful, comparatively speaking, from July to February, after which the people are obliged to live on the poorest grains, dried fruits, and the green stuffs of the spring. Their food is entirely vegetable. Flesh meat is an article of diet far beyond their means, while salt is a luxury to all except the richest families.

That the disease may be introduced into a community where it has not previously been and that in such cases the water supply becomes at once the suspected agent of distribution is shown by McCarrison's remarkable observation in Nagar.

In the village of Nagar goiter was unknown six years ago. Nagar is a small State situated up one of the many side valleys on the left bank of the Gilgit River. It will be remembered as the scene of a smart frontier rising in 1893. It was after this year that the little State of Nagar began to be opened up; previously, jealous of its independence and at war with its immediate neighbors, it was careful to exclude foreigners. During recent years intercourse with the outside world has become more free, but still there is a decided prejudice against the settling of foreigners in this little hill State.

Some five years ago certain cases of goiter were introduced from without, and since then the disease has begun to gain a footing. It may be as well to indicate clearly that there can be no doubt about the fact that goiter was quite unknown six years ago. The fact that it has gained a footing in his territory is a matter of very considerable anxiety to the present rajah, and through his help I was enabled to go into the matter with great care. All the important men of the State, the rajah himself, councilors, priests, etc., assure me that no case of goiter ever originated in Nagar till within the last six years.

There is a family at present at Nagar which consists of nine souls; of these three came from Gilgit some years ago, all suffering from goiter. Two, the father and the mother, have no goiters, the father came from Gilgit. The remaining four individuals have never been outside Nagar. Three are high-caste Mohammedan girls (16, 15, and 10 years of age), which makes the statement the more likely to be accurate. The fourth individual is a boy aged 12; he has never been outside Nagar. All of these four developed goiter about two years ago. This family lives in the same house, that is, the same room, eat out of the same vessels, etc. It is to be observed that these, the first victims, are all young.

Another family consists of a man, his wife, and son, aged 2, and the man's brother, aged 20. The man brought goiter with him from outside five years ago. Two years later his brother developed the disease, though he had not been outside Nagar for five years. The little boy, aged 2, developed the disease one year ago; the wife is free from it. Another man, aged 23, brought the disease from Gilgit one year ago; it is increasing in size here.

Twelve children, all under 10 years of age, were brought to me having marked enlargements of the gland. There are no other cases of the disease in Nagar. The children were from different houses scattered over the village. The first family to which I referred lives at the head of the spring which supplies the village with drinking water.

The village supply consists of a spring which comes out of the hills; it is not the only supply of the village. The cases I have referred to all drank from this water. This spring is said to have been in existence from time immemorial; the chemical composition of its water has presumably not altered. The conditions of life of the people are the same. The only added factor in the case is the introduction of the disease from without. That it is spreading there can be no doubt, and that the course of the spread is a typically endemic one is equally evident. It is easy to understand why the disease should not have reached Nagar earlier, as it is only within recent years that the communications of Nagar with the outside world have become free.

It appears evident also that it is by means of the spring water that the disease is now spreading, for the 12 children are residents of that part of Nagar supplied by the spring, and their homes are scattered here and there among the houses of the yet unaffected inhabitants. Further, the fact that the first family referred to lives at the head of the spring is of importance, and also that no cases of this disease were observed where water from other sources only is drunk, that is, in the distant parts of the village where the nullah water or the river water is used.

It seems likely, therefore, that some poison, goiter producing in its powers, has been introduced into a water supply which happened to be suitable for the conveyance of this disease.

This case of Nagar can not be explained by any theory which attributes to dissolved ingredients in a water goiter-producing properties; nor can inorganic matters in suspension account for this outbreak; for it can not be supposed that from causes in the water which have existed from time immemorial a disease should suddenly spring. There is, to my mind, only one explanation, namely, the introduction of an organism into the water supply.

TABLE VIII.—FEEDING AND OTHER EXPERIMENTS WITH WILD BROOK TROUT.

Tank.	Lot.	Fish.	Food.	Other conditions.	Fish added Sept. 21, 1910.	Clinical condition, June, 1912. ^a			
						Remain- ing.	Clean.	With red floors.	With tu- mors.
1.....	2146	50	Heart, raw.....		0	² 39	21	17	1
2.....	2147	50	Liver, raw.....		27	34	30	4	0
3.....	2148	50	Marine fish.....		5	1	0	1	0
4.....	2149	50	Liver, raw.....	Reduced space; crowding.....	14	37	26	11	0
5.....	2150	50	Vegetable.....		4	1	1	0	0
6.....	2151	50	.....do.....	In presence of tumor fish.....	0	0	0	0	0
7.....	2152	50	Liver, cooked.....		25	20	16	4	0
8.....	2153	50	Liver, raw.....	In presence of tumor fish.....	7	36	28	8	0
9.....	2154	50	Natural food.....	Minimum feeding.....	0	(b)	0	0	0
10.....	2155	50	Liver, raw.....	Forced feeding.....	13	38	35	3	0
11.....	2156	50	Natural food.....	Controls.....	26	40	40	0	0
12.....	2159	25	.....do.....	Pond to mud in tank.....	0	22	21	1	0
13 upper.....	2160	16	.....do.....	Inoculated in thyroid region.....	0	9	5	4	0
13 lower.....	2161	14	.....do.....	Inoculated in thyroid region with trout thyroid tumor.....	0	12	12	0	0
14.....	2162	20	.....do.....	Pond to mud in stomachs.....	0	16	15	1	0
15.....	2163	27	.....do.....	Inoculated in thyroid region with trout thyroid tumor.....	0	12	9	3	0
16.....	2164	17	.....do.....	Inoculated behind eye with fil- trate from pond to mud.....	0	4	3	1	0

Tank.	Sec- tions, 1911.	Diagnoses, 1911.	Sec- tions, 1912.	Diagnoses, 1912.
1.....	2000	A, hyperplasia; B, carcinoma.....	2098	A, tumor, carcinoma; B, adeno-carcinoma.
2.....	2001	A, beginning hyperplasia; B, normal; C, carci- noma.....	2099	A, B, C, regression.
3.....	2002	Normal.....	2100	Normal.
4.....	2003	Beginning carcinoma.....	2101	Regression.
5.....	2004	A, B, C, normal.....	2102	Normal.
6.....	2005	Normal.....		
7.....	2006	A, B, normal.....	2103	Regression.
8.....	2007	A, B, beginning hyperplasia.....	2104	A, B, regression.
9.....	2008	A, B, C, normal.....	2113	Normal.
10.....	2009	A, B, normal.....	2105	Regression.
11.....	2010	B, C, normal.....	2106	Normal.
12.....	2011	A, B, C, normal.....	2107	Increased thyroid of normal type.
13 upper.....	2012	A, B, normal.....	2108	Increased thyroid of normal type.
13 lower.....	2013	A, B, normal.....	2109	Normal.
14.....	2014	Normal.....	2110	A, normal; B, increased thyroid of normal type.
15.....	2015	A, normal; B, C, beginning hyperplasia.....	2111	Increased thyroid of normal type.
16.....	2016	Normal.....	2112	Increased thyroid of normal type.

^a Examinations of Nov. 30, 1910, and July, 1911, all were clean.^b Transferred to pond 10.

DESCRIPTION OF SECTIONS TO ACCOMPANY TABLE VIII.

2000 B. Tubulo-alveolar type of carcinoma. Marked infiltration of surrounding areolar tissue. Infiltration of muscle above into bone spaces and infiltration of vessel wall. Invasion of cartilage.

2001 A. Beginning hyperplastic stage. Certain follicles are lined with columnar epithelium. In many such follicles colloid is absent, in others present but poorly stained. Surrounding this group of follicles are follicles of strictly normal appearance. Epithelium flattened, filled with colloid. Beginning of the hyperplasia in this specimen is evidently limited to individual follicles (Fig. 84.)

2001 B. Most of the thyroid tissue in this specimen is of typical normal appearance, flattened epithelium, follicles filled with stainable colloid.

2001 C. The entire space surrounding the vessel is filled with closely packed alveoli, small sized alveolar structures lined with high columnar epithelium, with deeply staining vesicular nuclei. Colloid is almost entirely absent. Evidently growth of the thyroid tissue which has spread upward into the areolar tissue immediately below the mucosa of the floor of the mouth. Under high power the nuclei present great variability in size, the staining qualities are vesicular with one or two nucleoli. Marked evidence of hyperemia between the follicles. Many tubules are filled with closely packed cells. In some portions of the growth all alveolar structure has disappeared and small islands of closely packed cells are found. Infiltration of dense connective tissue structure, perichondrium and periosteum. Beginning carcinoma of tubulo-alveolar type.

2002 B. The amount of thyroid tissue surrounding the vessels is very scarce. Vesicles small, epithelium flattened, filled with stainable colloid. Normal thyroid.

2003 A. Alveoli small and lined with high columnar epithelium, deeply staining nuclei. Colloid absent. Follicles few in number and poorly staining. Occasional groups of vesicles of normal appearance. Beginning invasion of areolar tissue. Dense connective tissue structure. Growth into bone cavities. Definite alveolo-tubular type beginning carcinoma.

2004 A, B, C. Space about vessels rather well filled with small-sized vesicles relatively uniform in size. Epithelium is flat, tened. Vesicles are filled with stainable colloid. In one small area close to a large vessel are a half dozen follicles in which the colloid is small in amount, the epithelium cubical. Normal thyroid.

2005 A. This is evidently one of the tumor fish introduced into this experiment. Large amount of thyroid tissue. Great variability in the size of the follicles. Large regular shaped follicles lined with flattened epithelium and filled with stainable colloid. Large numbers of small follicles with cubical or flattened epithelium. Varying amount of colloid. Large amount of hyaline connective tissue stroma. Obviously a tumor which has undergone regression. Tumor tissue fills the entire space around the vessel, penetrates to the floor of the mouth, and into the bone cavities. It has previously invaded and destroyed large areas of muscle. Contains numerous nematode tubercles, in which no worms are to be found. Spontaneous recovery. See further under that heading.

2005 B. Very few follicles included in this section. Flattened epithelium filled with stainable colloid. Typical vesicles. Normal.

2005 C. Evidently tumor fish introduced into this experiment with spontaneous recovery like 2005 A. Contains two nematode tubercles, in one of which remnants of a worm can be seen.

2006 A, B. Thyroid consists of typical vesicles with flattened epithelium filled with stainable colloid. Normal.

2007 A. Space around the large vessels contains scattered follicles filled with stainable colloid, lined for the most part with flattened epithelium. There is marked hyperemia, marked engorgement of the vessels between the follicles, and evidence of small extravasation about the follicles. A few follicles are lined with cubical epithelium. Hyperemia of the thyroid, possibly beginning hyperplasia.

2007 B. Tissue badly preserved, evidently overheated in embedding. Shows section of media of aorta around which are areas of closely packed large follicles, lined with cubical epithelium. No colloid. Beginning hyperplasia.

2008 A, B. Small follicles lined with flattened epithelium, filled with stainable colloid. Normal.

2008 C. Thyroid tissue in this fish consists of rather compact masses in the region of the large vessels. The epithelium of some follicles is slightly cubical. Follicles are filled with stainable colloid. Some evidence of hyperemia in the vessels between the follicles. Slight hyperemia of the thyroid. Probably normal.

2009 A, B. Follicles oval and spherical, lined with flattened epithelium, filled with stainable colloid. Normal.

2010 B. Vesicles lined with flattened epithelium, filled with stainable colloid. Normal. Around the large vessels the thyroid follicles are closely packed; the colloid is reduced in amount but stains deeply. Epithelium is small, cubical. Probably normal. Thyroid tissue greatly increased in amount but of normal appearance.

2010 C. Spherical and oval follicles lined with flattened epithelium filled with stainable colloid. Normal.

2011 A. Follicles lined with flattened epithelium, filled with stainable colloid. Between the follicles hyperemia of the vessels. Some evidence of extravasation. Hyperemia of the thyroid. Probably normal.

2011 B, C. Spherical and oval follicles lined with flattened epithelium, filled with stainable colloid. Normal.

2015 B. Closely packed follicles of irregular shape with almost complete absence of colloid. Follicles lined with cubical epithelium. Small groups of detached follicles lying outside the closely packed area lined with flattened epithelium and filled with stainable colloid. First evidences of hyperplasia. Beginning simple hyperplasia.

2015 C. Between the second and third gill arches the space is filled with loosely arranged follicles, many of which contain stainable colloid and are lined with slightly cubical epithelium. Between the follicles, marked hyperemia and engorgement of the vessels. Away from this mass in this area of slightly altered thyroid one finds isolated typical normal follicles with deeply staining colloid and flattened epithelium. Again, about the aorta above and below it, one finds one or two aggregates of follicles with slightly cubical epithelium and evidences of hyperemia. The remainder of the thyroid tissue about the large vessels strictly normal. Hyperemia of the thyroid, possibly beginning hyperplasia. Unusual amount of thyroid tissue.

2098 A. Tumor. Typical alveolo-solid carcinoma for the most part, with areas of papillary formation. Infiltration of muscle, bone, and cartilage. Infiltration of wall of vein. Papillary adeno-carcinoma infiltrating muscle bone and cartilage. Hyaline degeneration of the wall of the media of the aorta. (Fig. 90.)

2098 B. Beginning adeno-carcinoma of tubulo-alveolar type. Infiltration of areolar tissue, dense connective tissue structures, periosteum of bone and muscle.

2099 A. Examination of this section shows an unusual amount of thyroid tissue about the large vessels, small follicles lined with flattened epithelium, some of them containing stainable colloid, others poorly stained colloid, many of them empty, pushed in flattened strands between the dense connective tissue structures, spreading well forward into the areolar tissue and in the adjacent bone cavities. (Fig. 91.) Great increase in the amount of thyroid tissue. Only one or two large follicles filled with stainable colloid. Immediately adjacent to the large vessels a few follicles with high cubical epithelium and no colloid. The whole specimen indicates the previous existence of well-developed hyperplasia followed by regression.

2099 B, C. Presents the same histological characteristics. Increased amount of thyroid tissue. Many isolated groups widely distant from the large vessels. About the large vessels are many tortuous elongated and branching alveoli of tubular type, lined with flattened epithelium, free from colloid. (Fig. 92, under "Spontaneous Recovery.") Colloid almost entirely absent.

2101 A. Small closely-packed follicles lined with flattened and low cubical epithelium. No colloid. Marked increase in amount of thyroid tissue. Many follicles and flat strands of follicles between the muscle bundles in the areolar tissue, floor of the mouth, and bone cavities. Regression from well-developed hyperplasia.

2103 A. About the large vessels are individual follicles lined with columnar epithelium, filled with faintly staining colloid. These follicles are irregular in shape. Slight infoldings of the vesicular wall with beginning bud formation. Protoplasm of the cells stains deeply. The nuclei are vesicular, of great variety of size. The long axes of the nuclei are perpendicular to the circumference. Marked hyperemia of the small vessels between these follicles. In the same field by low power may be seen individual follicles of typical normal appearance, flattened epithelium filled with deeply stainable colloid. We have here beginning focal hyperplasia. Certain groups of follicles are lined with flattened epithelium, contain no colloid, are elongate, branching or irregular in shape, and present an appearance suggesting regression of individual follicles.

2104 A, B. Marked increase of thyroid. Follicles closely packed and spherical, some filled with stainable colloid. Some follicles of irregular shape or branching. Widely scattered follicles in the areolar tissue and between the fibers of the dense connective tissue structures. Regression of hyperplasia.

2111 A. Spherical and oval follicles filled with stainable colloid and lined with flattened epithelium. Engorgement of the vessels between the follicles. Slight hyperemia. Normal.

CHEMOTHERAPY.^a

THE EFFECT OF IODINE, MERCURY, AND ARSENIC UPON CARCINOMA OF THE THYROID.

The knowledge of the occasional effect of iodine as a remedy in goiter is almost as old as our knowledge of the disease itself. The relation of iodine to the thyroid has been the subject of extensive study by modern chemical methods and by biological experiment. It is well known that the thyroid gland normally contains iodine, and it has been contended that in certain hyperplasias of the thyroid the amount of iodine per gram weight of thyroid tissue is reduced. These facts have led experimenters to hold that the curative effects of iodine upon the hyperplastic thyroid is more due to a restoration of the iodine content to a normal basis than to the specific action of iodine administered as a remedy. In the mammalian hyperplastic thyroid there are frequently encountered small adenomata which are more or less distinct in appearance from

^a The measures to be taken by fish culturists for the prevention of thyroid carcinoma must await a careful investigation planned specifically with this end in view. This we have not been able to undertake. We believe, however, our experiments with wild fish point the way along which efforts should be directed.

The matter of food is undoubtedly the most important aspect of domestication in relation to thyroid disease. The livers of cattle, sheep, and hogs are chiefly relied upon in rearing the salmonoids, and the extent to which this food is varied or replaced by heart, lungs, horse flesh, and other animal proteids apparently does not alter the situation in this respect. Their availability as fish food makes it difficult to displace them, but fortunately they are not inherently necessary to fish culture. Vegetable food made from staple grains, fresh-water and marine fish and mussels, Entomostraca and other Crustacea, live maggots and even living adult insects, have been used more or less as foods in practical fish culture. Most of these are not yet available in quantity, and none has displaced entirely the mammalian proteids. Our feeding experiments, however, indicate that such foods would maintain normal thyroid glands in the salmonoid fishes. To devise and prove a composite ration properly balanced for this purpose would seem a fish cultural problem worth while. Perhaps a cooked mixture consisting largely of vegetable meal in which was incorporated fish flesh and a minor portion of one of the foods used commonly at present would promise best. Possibly even small quantities of insects and insect larvæ added to this would be an important improvement. Such a food has ever been a prime desideratum in fish culture and affords a measure of protection against most fish diseases as well as against the one now under discussion.

Holding the disease to be an infection, the ultimate problem is largely one of prevention, under which would come a more stringent cleanliness of fish troughs and ponds, possibly the annual painting of wooden containers and in the case of dirt ponds, their occasional emptying with periods of sun-drying, or a change to cement construction. The selection and breeding of resistant strains, or of resistant species like the Scotch sea trout, are obviously indicated.

As for the presumption, which experiments indicate, of remedial possibilities in the use of mercury or iodine, there is no sufficient basis at present for recommending their use on a practical scale. This would involve their administration over considerable periods of time which their cumulative action might render undesirable. Moreover, that they are absolute preventives of the disease process under discussion is not yet demonstrated. The control of this disease can doubtless be brought about by other means than administration of chemical agents. To this end a fish-cultural station handling preferably the brook trout could well be devoted to the extended experiments having to do with feeding and the access of infection to the fish which are necessary both to more exact knowledge of the disease and to its practical relations.

the surrounding hyperplastic tissue and have been looked upon as developing from embryonic rests, especially rests of the original tubular structure of the fetal gland. From these adenomata the malignant neoplasms of the thyroid are supposed to take their origin.

Marine and Lenhart (1910b, p. 20; 1911a, p. 22), who have extensively studied the effect of iodine upon the mammalian thyroid, have advanced the theory that hyperplasias of the thyroid including endemic goiter are due to insufficiency of iodine in the diet of the individuals and that the therapeutic effects of iodine are the result of restoring to the thyroid the normal amount of iodine. They state that nodular struma or the adenomas found in strumous thyroids are unaffected by iodine, and that malignant tumors are unaffected by iodine, and they propose that the administration of iodine shall constitute a biological test for the purpose of distinguishing between hyperplasias which they hold to be due to a physiological deficiency of iodine and malignant tumors which they state can not be affected in this way. The evidence of the microscope is no longer to be considered; the final test is to be whether or not a given enlargement of the thyroid responds to iodine. It is obvious that such a test as Marine and Lenhart have proposed is not applicable to malignant tumors other than the thyroid, as it has long been known in experimental cancer research that transplantable mouse cancer is definitely influenced in its growth by many chemical compounds (Clowes, 1908), particularly the heavy metals.

Schoene (1910) showed that for a time regression of advanced implanted mouse cancer could be induced by the intraperitoneal injection of iodine and mercury in the form of KI and HgCl_2 . He found the effect of mercury to be much more marked than that of iodine. It was thus known that iodine had an inhibitory effect upon genuine neoplasms and it therefore seemed possible that the action of iodine upon the proliferating thyroid might be due to some specific action upon the tissue, such as these experiments of Schoene's indicated the agent possessed for genuine neoplasms of other organs. Marine and Lenhart reported in 1910 that fish suffering with hyperplasia of the thyroid were favorably affected by adding iodine in the form of Lugol's solution to the water in the troughs in which they were kept, and from these observations applying the theory above stated, concluded that the so-called carcinoma of the thyroid in the Salmonidæ was not carcinoma but simple hyperplasia, distinguishable from true neoplasms by the favorable effect of iodine upon the tissue. The remarkable infiltrative character of these neoplasms, so well described by Scott, Plehn, and Pick, and reported in our first preliminary reports, Marine explains as due to the absence of a capsule. This feature of the case we have dealt with under the appropriate heading and it need not be again referred to here.

The results of Marine and Lenhart in causing regression or, as they term it, involution or reversion, of the hyperplastic thyroid in the Salmonidæ by the administration of iodine through the water, we have been able to confirm. In order to determine whether the action of the iodine was peculiar to this element and might therefore be looked upon as acting upon the thyroid by virtue of its physiological relation to this organ, in repeating the experiments of Marine and Lenhart we decided to control them

by treating under exactly the same conditions comparable fish with mercury in the form of HgCl_2 . This gave the further advantage that if mercury should prove to have a similar effect upon the thyroid to that determined by Marine and Lenhart for iodine, the relation of these growths of the thyroid to one of the heavy metals might be determined, mercury already having been shown to have an inhibitory and regressive effect upon genuine neoplasms. The experiments were carried out in the summer of 1910 with the result, as may be seen by the accompanying tables, that mercury was found to have an effect upon the growing thyroid of the Salmonidæ indistinguishable from that obtained with iodine, with the exception that mercury appeared to produce these results more certainly and more rapidly than did iodine. To further amplify the

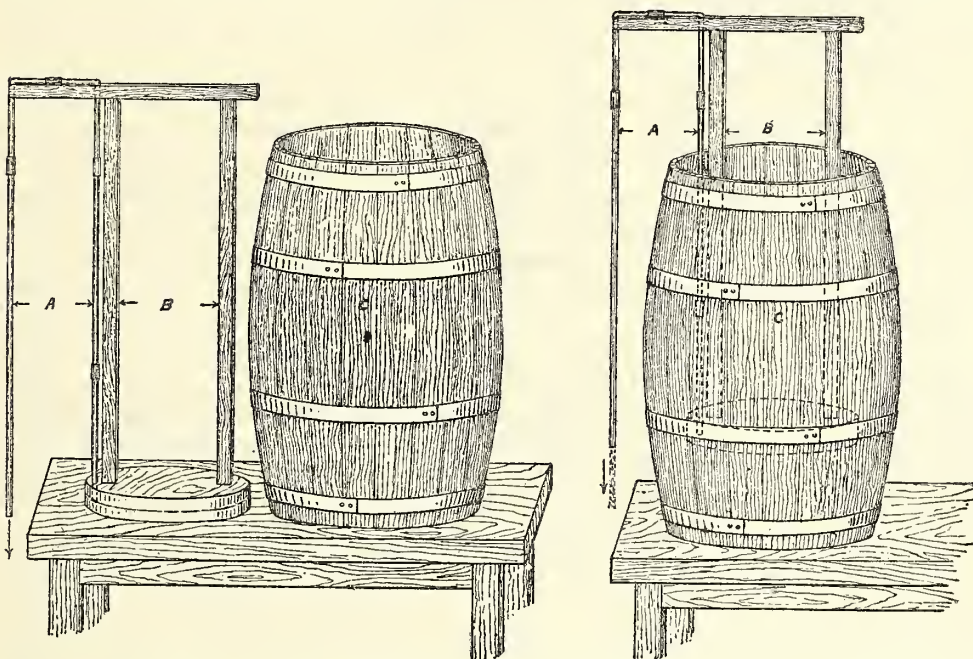


FIG. 95.—Floating siphon. *A* is the siphon, *B* the frame, and *C* the container. The form of the frame is of course not essential, and should be adapted to the container. The illustrations show the glass tubing of much larger size than is necessary or practicable in small siphons. Small tubing is preferable.

comparison, during the summer of 1911 experiments with arsenic, an element long known to have a favorable influence upon genuine neoplasms, were carried out, using arsenic in the form of As_2O_5 . These results are also sufficiently set forth in the tables.

Experiments were begun by determining the toxicity of the iodine to trout when added to the water in the form of the pure element already dissolved in distilled water and then added to the dissolved potassium salt. The uncombined iodine is much more toxic than the potassium iodide. Lake trout fry were killed in less than 20 hours by one part of free iodine added to 400,000 parts of tap water. Dilutions of 1 to 1,000,000 are safe, perhaps because the iodine is combined before it has time to produce a fatal

result. At 1 to 600,000 brook trout yearlings were not killed during three days, but the effect of iodine was seen in coagulating the slime on the bodies of the fish.

In the form of potassium iodide, 1 part of iodine in 25,000 parts of tap water killed brook trout fry in two to six hours, but 1 to 50,000 was harmless during a trial of two weeks. Lake trout fry were uninjured by dilutions of 1 to 200,000 and weaker.

The administration of the chemical agents has been accomplished in several different ways and in various dilutions. The constant uniform dilutions were maintained by running a solution of known strength continuously into the fish troughs with the measured water inflow at the head of the trough, an intimate mixture being insured. A barrel was used as a receptacle for the solution and a constant head for the flow of solution was maintained by the use of a floating siphon. (Fig. 95.) In this way it is easy to keep the water supply of the experiment constantly impregnated to any desired degree with any soluble agent.

The intermittent treatments were applied by adding single doses of the chemical to the water of the fish trough, obtaining fairly complete distribution by stirring. Two daily doses were given, and the water supply was so adjusted as to change the contents of the trough every four-hour period. The dilution of the chemical then proceeded with the flushing out of the trough by the water flow. The corners of the trough may have still held appreciable quantities of the agent after the four-hour period, but the flow must have diluted it beyond any effective strength long before the succeeding portion was added.

Experiment 1 (table ix).—Iodine administered as potassium iodide and given continuously under constant head from a floating siphon into a trough receiving an adequate and measured water supply direct from Craig Brook and having a definitely known outflow. The water supply was 24 liters per minute. The siphon flow of KI solution was so regulated that a constant concentration of iodine of 1 : 5,000,000 was maintained in the flowing water. The temperature of the water during the course of the experiment varied but little from 19.5° C. The fish were fed raw beef liver. The following fish were subjected to this treatment: Three tumored hybrid salmon, 6 tumored brook trout, and 15 clinically clean brook trout. An equal number of controls living under identical conditions, with the exception of the presence of iodine, were carried through for comparative study. The greatest period during which fish were subjected to this treatment was 31 days. Treated fish and controls were preserved for study, however, at frequent intervals during the course of the experiment. A brief statement of results is given in table ix. This is self-explanatory. (Fig. 96, 97, 98, 99, 100, 101.)

Experiment 2 (table x).—Similar in all respects to experiment 1, except for the concentration of iodine, which was much greater, being 1 : 300,000. The fish were fed raw beef liver. The fish subjected to the treatment were as follows: Four clinically clean brook trout, 5 brook trout with pharyngeal discoloration (red floor), and 6 brook trout with various tumors. Parallel controls for all these fish were also studied. The longest period of treatment in this experiment was 17 days. Macroscopic evidence of regression was furnished in some of the red floors and in some of the tumor fish as shown by the disappearance of pharyngeal reddening and reduction of tumor measurement. The results of microscopic study of these specimens, together with their controls, are given in table x.

Experiment 3 (table xi).—In this experiment iodine was administered intermittently as potassium iodide, the greatest concentration of iodine in the water at any one

time being 1 : 32,000,000 parts. From this strength dilution rapidly occurred, reaching infinity in about four hours, the time required for the replacement of the water contents of the trough containing the fish experimented upon. The iodine was administered twice daily, morning and evening, so that there were long periods during which the fish received no iodine. The temperature of the water remained quite constant at 19.5° C. These fish were fed raw beef liver. The longest period of administration was 30 days. The fish employed were 15 clinically clean brook trout yearlings and 5 small tumor brook trout yearlings. No special controls were employed for this experiment, comparisons being made with the controls for the previous iodine experiment. Here again some macroscopic evidence of regression was furnished by diminution in size of tumors. A brief résumé of the microscopic study is given in table XI.

Experiment 4.—A small number of fish were tested for the toxicity of iodine administered as Lugol's solution into the stomach, and it was found that yearling trout will endure as much as 1 to 5 mg. and adult trout as much as 10 mg. A number of fish were treated, some of them during a period of 21 days, with injections into the stomach of Lugol's solution containing from 1.16 mg. to 3.75 mg. iodine. Some of these died, probably through the cumulative effect of the iodine. Definite reduction of tumors was observed. Microscopic evidence of regression, although in the main not as marked as that occurring in other methods of treatment, is nevertheless definite.

Experiment 5, showing the influence of mercury (table XII). This experiment is comparable with experiment 1 showing the effect of iodine administration. Mercury was administered as HgCl_2 , under constant flow, in a dilution of 1 : 5,000,000 of mercury. The following fish were subjected to this treatment: Fifteen clinically clean yearling brook trout, 5 brook trout showing red floors, and 3 brook trout with tumors. Parallel controls receiving no mercury were employed. Fish were killed and preserved at frequent intervals, the longest duration of treatment being 30 days. The experiment was begun August 13, 1910. The temperature of the water was 20° C.; feeding, the same as for other experiments. Here, also, macroscopic evidence of regression was furnished by clearing up of red floors and diminution in size of tumors, and in the almost complete clinical disappearance of a tumor 7½ mm. in diameter. A brief summary of the results of microscopic study is given in table XII. (Fig. 102, 103, 104, 105, 107, 108.) Three days is insufficient to affect tumors. In one case, however, after three days in 1 : 5,000,000 the fish was placed in 1 : 300,000 and was killed by the mercury in three and one-half hours. The epithelium showed great reduction. (Fig. 106.) Another after three days in 1 : 5,000,000 and 2.75 mg. of HgCl_2 introduced into the stomach on the second day showed no reduction.

Experiment 6 (table XIII).—Intermittent administration of mercury as HgCl_2 ; comparable to experiment 3 (intermittent administration of iodine). Mercuric chloride was introduced into the water of the trough containing the fish experimented upon in such quantity as to make a solution, for the moment, representing 1 part of mercury in 38,600,000 parts of water. This was done twice daily, at 10 a. m. and 4 p. m. The dilution was estimated to have reached infinity in four hours. Five tumored brook trout and 10 clinically clean landlocked salmon were subjected to this treatment for periods of 15, 31, and 43 days.

With this high dilution of mercury, even at the end of 43 days there was no definite macroscopic evidence of reduction in size of any of the tumors. The histologic study of the 15 fish of this experiment, together with 1 tumor and 1 clinically clean control, appear briefly summarized in table XIII. Of the 15 fish subjected to treatment, 5 show distinct evidence of regression, either in thyroid hyperplasia or tumor; 2 show slight regression; 2 are doubtful; and 3 show no evidence of change.

The results, therefore, from mercury in such high dilution and given intermittently, are less marked than with the high iodine dilutions and the less dilute mercury and arsenic. Nevertheless, as compared with controls, even given in these extremely small quantities, there is an undoubted effect from the mercury.

Experiment 7 (table xiv).—Arsenic administered in continuous flow, as As_2O_3 , delivered constantly, drop by drop from floating siphon, making a dilution equivalent to 1 part of arsenic in 300,000 parts of water.

Five clinically clean landlocked salmon and five tumored trout were subjected to this treatment. On the fourteenth day of the experiment the following fish were killed and preserved for microscopic examination: One with throat tumor, one with a throat and mouth tumor, and two clinically clean. In addition, two controls, one tumored and one clinically clean, were preserved for comparison.

At the end of the twenty-second day the experiment was discontinued and the remaining fish preserved. These consisted of three originally clean landlocked salmon and three originally tumored brook trout. Of the latter, there was only one visible tumor left and that greatly reduced in size. In another a red floor was the only visible sign of what was originally a fair sized tumor. (Fig. 109.) In a third there was no macroscopic evidence of the former tumor.

Microscopically all the thyroids of the fish subjected to treatment showed distinct evidence of regression. This was most marked in the fish in which treatment had been continued for 22 days. The controls, on the other hand, had undergone no regression. The results of microscopic study are briefly outlined in table xiv.

During the winter of 1910, in order to determine whether the results obtained by the administration of thymol in endemic goiter by McCarrison could be duplicated by the administration of this drug through the medium of the water upon fish with carcinoma of the thyroid, the following experiments were carried out: Thymol at 1 part to 500,000 of water, dissolved by the aid of heat maintained constantly in flowing water for 34 days, was without recognizable effect macroscopically or microscopically upon either visible tumors or the early stage. The temperature of the water ranged from 2° to 3°C . A brook trout yearling was killed between the second and third day by thymol at 1 to 200,000, indicating that solution of the thymol in the water was attained.

Generally speaking, iodine, mercury, and arsenic produce changes in the proliferating thyroid tissue, both in the early and advanced stages of carcinoma of the thyroid, which are scarcely distinguishable from the changes found in spontaneous recovery. In the early stages the change consists in a reversion of the columnar epithelium to the flattened form, return of stainable colloid, disappearance of hyperemia, and the partial disappearance of the most remote extensions of follicles in the outlying tissues. Where regression occurs rapidly in large tumors the first evidences of regression are found in extensive hemorrhages into the substance of the tumor; in some instances extensive areas of the tumor are the seat of hemorrhage. Such hemorrhages are organized by connective tissue. (See fig. 101.) The high columnar epithelium, especially in the peripheral portions of the tumor, are changed to flattened and atrophic cells with greatly diminished protoplasm. The retrograde changes are most marked at the periphery, and the entire picture is like that described under spontaneous recovery, except that the process seems to be more rapid and more extensive under treatment with metals. The effect of the metals, particularly mercury, is found as soon as the eighth

day, and in one instance where a fish with a large tumor (fish 1136 of table XII, fig. 108) was subjected to mercury by immersion for three and one-half hours in water containing a much higher concentration than usual, by which it was apparently poisoned and promptly died, the changes in the tumor were comparable to results obtained only by an exhibition of mercury at 1:5,000,000 during a period of not less than 20 days.

Since the experiments above referred to were completed, our knowledge of the action of the heavy metals upon carcinoma in experimental animals has been amplified by the experiments of von Wassermann, who has shown that the intravenous injection of selenium in combination with eosin, when given in large doses, is capable of causing the complete regression of large implanted mouse cancers, followed by clinical cure. In considering the results obtained by ourselves in carcinoma of the thyroid in the Salmonidæ, showing the pronounced effect of iodine, arsenic, and mercury, it became evident to us, after the publication of von Wassermann's results obtained with selenium, that it was highly probable that suitable compounds of any of the heavy metals would prove to have a more or less distinctive effect upon neoplasms. That this is the case is now shown by the publication of Neuberg, Caspari, and Löhe (1912) and the results obtained by the use of colloidal metals by Szécsi (1912), and the favorable, although temporary results obtained by the French observers in the use of colloidal copper in human carcinoma.

All of these experiments, as did the original observations of Schoene, dealt with large doses, in many instances almost a fatal dose of these metallic compounds given intravenously. Lewin (1913) has recently pointed out that where immediate results are obtained with metals, there is evidence of marked hemorrhage into the tumor, and believes that they are able to affect the tumor by their ability to injure the capillary terminals, this explaining the hemorrhage. Although in our experiments arsenic and mercury were used in very great dilution, we have the same evidence of hemorrhage into the tumors, especially the large ones that are obtained by injecting much larger doses intravenously in animals. It seems highly probable that the results obtained with this great dilution are due to a cumulative action of the metal. It is, however, clear that the results obtained in our experiments are of the same nature as those obtained in neoplasms of experimental animals by intravenous injection. (Gaylord, 1912 a.)

It seems assured that the action of iodine upon the tumors of the thyroid in the Salmonidæ is not due to its physiological relation to the thyroid gland; that its curative qualities are equally possessed by other elements, including the heavy metals, and that it acts by virtue of some quality which it shares in common with the metals; that these metals exhibit the same effect upon true neoplasms in mammals and that the effect of iodine and metals upon the tumors of the thyroid in the Salmonidæ tends to prove their true neoplastic nature, and that the theory of Marine and Lenhart that the action of iodine may be used to distinguish between physiological hyperplasia and true tumor formation is untenable.

19-day control	Follicles more numerous and more closely packed; many are distorted, with papillary epithelial ingrowths.	Less stroma	Less colloid	Very high, mostly col- lumnar.	Card 1092.
22 days, red floor	Great mass of thyroid nearly filling pharyngeal spaces, varying in type from compact follicles to compact epithelial cords and large islands of papilliform ingrowths with high col- lumnar epithelium. Infiltration of muscle and cartilage.	Variable; in some much connective tissue also hemorrhages and leucocytes; infiltration smooth muscle.	Small in amount, absent in most of growth.	High, cuboidal to col- lumnar in small part; in main mass epithelium is low, much of it completely re- duced.	Marked hyperplasia advancing tumor formation, mixed type, undergoing reduction, distinct, but not as marked as in some other specimens. Card 1058A.
Do	Poor sections, shows only small amount of thyroid; follicles more scattered.	Considerable in places; connective tissue.	Much colloid	Low	Marked regression. Card 1058B.
Do	Small amount spherical follicles widely separated, very few under floor and these small and widely separated.	Mostly loose areolar	do	Low; some low cuboidal most completely reduced.	Marked regression. Card 1058C.
Do	Relatively small number of well separated good-sized follicles. None near pharyngeal floor.	do	All follicles filled with colloid.	Low cuboidal to flattened.	Marked regression. Card 1058D.
Do	Small thyroid mass, mostly large follicles, some very large, only a few small follicles, near pharyngeal floor.	Small amount of connective tissue in main body, much under floor of pharynx.	Much colloid; large follicles distended with it.	Low, mostly low cuboidal to flattened; a few follicles, only in part lined with high cuboidal.	Red floor has disappeared; marked regression. Card 1053B.
Do	Same as preceding, except follicles still more loosely arranged, evidence of former invasion of cartilage replaced by areolar tissue.	Considerable connective tissue between follicles.	Much colloid, same as preceding.	Low, mostly complete reduction, occasional one or two follicles with high cuboidal.	Marked regression of red floor. Card 1055A.
23-day control, red floor	Loosely arranged follicles	Much loose areolar tissue; some blood.	Little colloid	High; much of it col- lumnar.	Moderate hyperplasia. Card 1081.
25 days	Relatively small number of follicles	Moderate connective tissue.	Much colloid	Low; mostly complete reduction.	Decided regression. Card 1075.
25-day control	Much more thyroid; more closely packed	Very little stroma	Half the follicles only contain colloid.	High; cuboidal to col- lumnar.	Moderate hyperplasia. Card 1076.
27 days	Relatively small groups of moderate size follicles.	Small amount of connective tissue, loose areolar.	Much colloid	Very low; almost completely reduced.	Marked reduction. Lot 2055 b; card 1069, fig. 99.
27-day control	Follicles vary more in size, shape, and arrangement; some more compact.	Moderate amount of connective tissue.	Much less colloid	High; mostly cuboidal.	Marked difference between this and I. fish. Lot 2055 b; card 1070, fig. 98.
29 days	Small number widely separated follicles.	Much loose areolar tissue.	Much colloid in all follicles.	Very low	Marked reduction. Card 1061.
29-day control	Small number well separated follicles, but more compact than in preceding.	Loose areolar	Less colloid than in preceding.	Moderately high; some high columnar.	Mild hyperplasia. Card 1062.
30 days	Relatively small in amount; widely separated follicles in loose areolar tissue. Some more closely packed.	Much connective tissue in some parts; others, loose areolar.	Much colloid	Low; mostly complete reduction.	Marked regression of hyperplasia. Card 1056A.
Do	Same as preceding.	Moderate amount of connective tissue.	do	Low	Marked regression. Card 1056B.

TABLE IX.—IODINE AS KI, CONTINUOUS FLOW; IODINE 1 TO 5,000,000—Continued.

[All domesticated brook trout and clinically clean unless otherwise stated.]

Duration of iodine treatment.	Histological condition of thyroid gland.					Diagnosis and general remarks.
	Distribution.	Infiltration.	Stroma.	Stainable colloid.	Epithelium.	
30 days.....	Same as preceding, except more thyroid.....		Moderate connective tissue.	Much colloid.....	Low.....	Marked regression. Card 1056C.
30-day control.....	Pharyngeal spaces nearly filled with more or less closely packed follicles; some very compact, but not reaching pharyngeal floor. Follicles mostly small; some infiltration of muscle and cartilage.		Small amount of connective tissue, smooth muscle.	Very little colloid.....	High cuboidal, and some columnar.	Moderately severe hyperplasia. Card 1057A.
Do.....	Less thyroid; otherwise same as preceding.....		Small amount of connective tissue.	.....do.....	High cuboidal, some columnar.	Moderate hyperplasia. Card 1057B.
Do.....	Small number of loosely arranged follicles.....		Considerable connective and loose areolar tissue.	Much colloid, but not in all the follicles.	Mostly high cuboidal; some low.	Mild hyperplasia. Card 1057C.
24 days, tumor.....	Tumor had shrunk 4 mm. from original diameter of 22 mm.; follicles separated by blood and leucocytes and connective tissue; large spaces surrounded by follicles, probably cysts.		Large, connective tissue, muscle, hemorrhages, leucocytes, loose areolar tissue.	Large in amount.....	Low cuboidal, in some flattened.	Marked reduction. Hybrid salmon. Card 1083; fig. 100.
30 days, tumor, throat.....	Small mass of follicles of varying size, only a few under pharyngeal floor, no present evidence of tumor.		Much connective tissue and loose areolar tissue.	Much colloid.....	Low cuboidal to flattened.	Very marked regression, tumor entirely reduced. Card 1053A; lot 2055B.
Do.....	Small mass, but larger than in preceding; smaller follicles, many very large.		Moderate connective tissue. Much loose areolar tissue.	.....do.....	.....do.....	Also marked reduction. Card 1053B.
30 days, tumor.....	Small mass of follicles, none near pharyngeal floor, many follicles large and irregular.		Considerable connective and loose areolar tissue.	.....do.....	.....do.....	Marked regression, tumor reduced. Card 1053C.
Do.....	Very similar to preceding; thyroid even smaller and follicles more separated. Irregular in size and shape.		Much connective and loose areolar tissue.	.....do.....	Low epithelium.....	Marked regression. Card 1053D.
Do.....	Very similar to preceding, but lying closer to pharyngeal floor.		Less connective tissue.	.....do.....	.....do.....	Marked regression. Card 1053E.
30-day tumor control.....	Large mass of irregular branching follicles, with papilliform ingrowing epithelium, completely filling pharyngeal spaces, invading muscle, cartilage, and bone.		Many isolated strands of smooth muscle blood-filled spaces, but no abscess formation or ulceration.	No colloid.....	Epithelium very high; high columnar mostly.	Rapidly growing tumor of the adenoma type. Card 1054A.
Do.....	Tumor of varying type; typical follicles closely packed; also papilliform ingrowing epithelial cords, invasion of muscle, cartilage, and bone.		Very little stroma, smooth muscle, some spaces filled with colloid (probably lymph).	Much colloid in some parts; none in others.	High columnar, high cuboidal, cubical.	Looks in part like colloid goiter in others like malignant tumor. Card 1054B.

30-day tumor control.....	Closely packed follicles; follicular arrangement lost in places, much invasion of cartilage, muscle, and bone, also involvement of gill regions, no ulceration.	Variable; considerable connective tissue in some parts muscle and many small hemorrhages.	Variable; some parts follicles well filled, others colloid absent.	High cuboidal, high columnar.	Tumor in part like colloid goiter, in other parts more like adenoma, and others like carcinoma. Card 1054C.
Do.....	Erosion of cartilage and muscle to some extent.	Small amount of connective tissue.	Very little.....	High columnar.....	Tumor of adenoma type. Card 1054D.
Do.....	Same as preceding.....	do.....	do.....	do.....	Same as preceding. Card 1054E.
31-day tumor.....	Differs from control in that the mass of thyroid consists largely of definite follicles.	Much connective tissue in places, areas of hemorrhages and leucocytes (abscess)?	Much more colloid than in control.	Mostly low cuboidal to cubical; some still high; much lower than in control.	Definite regression of tumor. Hybrid salmon. Card 1060; fig. 101.
31-day control for tumor fish...	Closely packed mass of epithelium, few follicles; infiltration; cartilage, muscle, bone, rapidly growing mixed tumor.	Variable; much connective tissue in places, smooth muscle, blood-filled spaces, colloid-filled spaces.	Only a few follicles containing colloid.	No follicular portion; high columnar, high cuboidal.	Advancing mixed throat tumor. Hybrid salmon. Card 1059.

TABLE X.—IODINE AS KI, CONTINUOUS FLOW; IODINE 1 TO 300,000.
[All domesticated brook trout.]

Duration of iodine treatment.	Histological condition of thyroid gland.				Diagnosis and general remarks.
	Distribution.	Infiltration.	Stroma.	Stainable colloid.	Epithelium.
5-day control, red floor.....	Closely packed follicles under pharyngeal floor.		Very little.....	Small amount.....	Moderately high throughout, columnar in places.
5 days, red floor.....	Loosely arranged mass of follicles under pharyngeal floor, extending downward and invading cartilage.		Much loose areolar tissue where thyroid is thinning out.	Much colloid.....	Very low, much completely reduced.
5 days, clean.....	Moderate size masses of loosely arranged follicles, medium size.		Considerable connective tissue.	.....do.....	Low cuboidal to complete reduction.
8-day control, red floor.....	Large mass, rather loosely arranged follicles, irregular size and shape.		.....do.....	Moderate amount of colloid.	High, mostly cuboidal, some columnar.
8 days, red floor.....	Moderately large mass of well-separated follicles of medium size.		.....do.....	Much colloid.....	Mostly low; some high cuboidal.
11 days, clean.....	Moderate number of widely separated medium large follicles.		Much connective tissue between follicles.	.....do.....	Moderately high.....
11-day control, clean.....	Larger amount of thyroid; more closely packed follicles.		Less stroma.....	Less colloid.....	High.....
17 days, clean.....	Well-scattered follicles.....		Much loose areolar.....	Much colloid.....	Low; in most complete reduction.
17-day control.....	More follicles.....		.....do.....	Less colloid.....	Moderately high.....
17 days, red floor.....	Moderate number of well-separated follicles.....		Considerable connective and loose areolar.	Much colloid.....	Complete reduction in most follicles; a few still high.
17-day control, red floor.....	Large number more closely packed, more irregular follicles, and lying under pharyngeal floor.		Less stroma, though considerable amount in parts.	Moderate.....	Moderately high, cuboidal to columnar.
Control for tumors.....	Mass of papilliform growing irregular follicles, filling pharyngeal spaces.		Moderate.....	Very little colloid.....	High, mostly columnar.
1-day tumor.....	Closely packed, distorted, irregular follicles; looks like adenoma; some large spaces filled with colloid.		Little.....	.....do.....	Very high columnar.....
3-day control tumor.....	Very atypical thyroid; very few follicles, much stroma.		Marked over growth of connective tissue stroma.	Small in amount.....	High.....

3 days, tumor	Large cystic tumor, many very large colloid-filled vesicles; much papilliform ingrowing epithelium, invasion of cartilage.	Much connective tissue in places.	Considerable colloid; many apparent colloid cysts.	Variable; mostly cuboidal, some higher, some lower.	Small but distinct reduction. Card 1147.
4 days, tumor	Small masses invading muscle, large masses under pharyngeal flow of variable sized follicles.	Much connective tissue at periphery of tumor.	Much colloid	Variable, mostly low ..	Distinct reduction. Card 1148.
4 days, tumor	No demonstrable diminution; some enormous colloid-filled spaces, lined by low epithelium; islands of epithelium in some follicles; very pronounced epithelial ingrowths.	Moderate connective tissue.	Fair amount	High, much columnar.	No appreciable reduction. Card 1154.
6 days, tumor	Tumor reduced 2 mm. in diameter; apparent thinning out of tumor mass and reappearance of follicles.	Considerable connective tissue.	Small amount	Moderately high	Apparently undergoing regression. Card 1155.
Control 17 days, tumor	Large mass; variable follicles; many very small and compact, some with ingrowing epithelium, invasion of muscle and cartilage.	Marked in places; many leucocytes.	.....do.....	High cuboidal, some columnar.	Mixed tumor; varies in type in different parts. Card 1151.
17 days, tumor	Throat and pit tumor	Marked in places	More colloid	Moderately high	Does not differ very much from control, only slight reduction if any. Card 1152.

TABLE XI.—IODINE AS INTERMITTENT KI; IODINE 1 TO 32,000,000, TWICE DAILY, REDUCING TO INFINITY IN FOUR HOURS.
[All domesticated brook trout, yearlings; all clinically clean save last four.]

Duration of iodine treatment.	Histological condition of thyroid.				Diagnosis and general remarks.
	Distribution.	Stroma.	Stainable colloid.	Epithelium.	
13 days.	Several masses of moderate numbers of follicles, medium size, not filling pharyngeal spaces.	Much connective tissue; loose areolar between masses.	Much colloid.	Low cuboidal to complete reduction.	Marked regression. Card 1071.
18 days.	Widely scattered follicles, varying sizes.	Much connective tissue.	Moderate.	High cuboidal, some low.	Very little effect. Lot 2055B; card 1166.
21 days	Moderate number of well-separated follicles.	Very little connective tissue, much loose areolar.	Much colloid.	Low mostly, very low cuboidal.	Decided reduction. Lot 2055B; card 1167.
24 days.	Moderate number of large follicles, varying considerably in size.	Much connective tissue in places.	. . . . .do.	Low cuboidal to flattened.	Decided reduction. Lot 2055B; card 1168.
27 days	Same as preceding, but fewer follicles.	Moderate connective tissue; much loose areolar.	. . . . .do.	Low; cuboidal to flattened.	Marked reduction. Lot 2055B; card 1169.
30 days.	Small thyroid mass, widely separated follicles; some very large.	Much loose areolar. . . . .	. . . . .do.	Very low.	Marked reduction. Lot 2055B; card 1170B.
Do.	Same as preceding, but more follicles.	Considerable amount of connective tissue in places.	. . . . .do.	Varies from moderately high to low.	Reduction, but not as well marked as in no. 10. Lot 2055B; card 1170C.
2 days, small tumor.	Undifferentiated mass of epithelial cells closely packed; a few scattered follicles; erosion of cartilage, and invasion of muscle.	Very little connective tissue; muscle.	Almost no colloid.	Very high.	Small throat and pit tumor; no reduction; may be used as control. Card 1099.
Do.	Closely packed follicles, varying in size, shape, and compactness, completely filling pharyngeal spaces; erosion of muscle and cartilage.	Some connective tissue; islands of smooth muscle.	Very little colloid.	High cuboidal to columnar.	Small throat tumor; no reduction; may be used as control. Card 1101.
Do.	Closely packed follicles; invasion of muscle and cartilage.	Moderate connective tissue and smooth muscle.	. . . . .do.	High; mostly columnar.	Small throat tumor; no reduction; may be used as control. Card 1102A.
Do.	More typical follicles; otherwise same as preceding.	. . . . .do.	Considerable.	High; cuboidal mostly.	No reduction; use as control. Card 1102B.

TABLE XII.—MERCURY AS $HgCl_2$, CONTINUOUS FLOW; Hg 1 TO 5,000,000.

[All domesticated brook trout clinically clean unless otherwise stated.]

Duration of mercury treatment.	Histological condition of thyroid gland.				Diagnosis and general remarks.
	Distribution.	Infiltration.	Stroma.	Stainable colloid.	Epithelium.
4 days.....	Small number of loosely arranged follicles, varying in size and shape		Much loose areolar tissue, little connective tissue.	Much colloid.....	High, throughout cuboidal to columnar.
6 days.....	Numerous follicles, varying in size, loosely arranged.		Considerable loose connective tissue.	.....do.....	Some columnar; some high cuboidal; some low cuboidal; some cubical and flattened; mostly moderately high.
6-day control.....	.....do.....		.....do.....	.....do.....	Mostly low, cuboidal in type, cubical, and in some follicles flattened.
7 days, red floor.....	Variable mass of typical and irregular follicles, more or less compact, with many spots of more loosely arranged follicles; evidence of former invasion of cartilage.		Some parts largely replaced by connective tissue and unstriped muscle; considerable hemorrhage.	Small amount of colloid.	Many follicles lined by low cuboidal, many by high, no columnar, mostly high.
8 days.....	Few well-separated follicles, mostly large.		Small amount of connective tissue, much loose areolar.	All filled with colloid.	Mostly low; many flattened, a few lined by low columnar.
8-day control.....	Loosely arranged follicles of varying size, large mostly; other masses more compactly arranged; some infiltration of cartilage and muscle.		Considerable connective tissue.	Colloid in about two-thirds of follicles.	Mostly high cuboidal to columnar, markedly higher than in 8-day Hg fish.
10 days.....	Relatively few follicles, well separated.		.....do.....	Most of the follicles contain colloid.	Low, cuboidal to flattened.
10-day control.....	More follicles, smaller than the preceding; more closely packed.		Less connective tissue.	Very little colloid.....	High; many follicles with high columnar.
10 days.....	Five fish; thyroid moderate in amount; typical follicles.		Considerable loose areolar.	Much colloid.....	Low, cuboidal; a few high cuboidal; complete reduction.
10 days, red floor.....	Large mass of follicles, varying in size.		Very little.	.....do.....	Moderately high.....
12 days.....	Relatively small amount of thyroid; medium follicles, well separated.		Considerable loose areolar.	Large amount.....	Low, cuboidal to complete reduction.
12-day control.....	Large amount of thyroid; distorted and irregular follicles, more closely packed.		Less stroma.....	Smaller amount.....	High, cubical to columnar.

TABLE XII.—MERCURY AS $HgCl_2$, CONTINUOUS FLOW; Hg 1 TO 5,000,000—Continued.

[All domesticated brook trout clinically clean unless otherwise stated.]

Duration of mercury treatment.	Histological condition of thyroid gland.				Diagnosis and general remarks.
	Distribution.	Infiltration.	Stroma.	Epithelium.	
14 days.....	Relatively small number of follicles.....		Moderate connective tissue; loose areolar.	Low cuboidal to flattened.	Marked reduction. Card 1084; fig. 105.
14-day control.....	Larger and more compact thyroid; some papillary ingrowths.		Small amount of connective tissue.	High, cuboidal to columnar.	Card 1085; fig. 104.
16 days.....	Small number of follicles.....		Very little connective tissue; loose areolar.	Low, in many complete reduction.	Marked effect. Card 1082-1.
16-day control.....	Larger number of follicles.....		More connective tissue; stroma.	High; in many high columnar.	Card 1082-2.
18 days.....	Relatively few follicles, well separated.....		Loose areolar.	Low, cuboidal to complete reduction.	Marked regression. Card 1077.
18-day control.....	Much more thyroid follicles, more closely packed.		Very little.....	High, cuboidal cubical, some columnar.	Card 1078.
18 days.....	Closely packed follicles, nearly filling pharyngeal spaces.		Moderate connective tissue.	Low, much desquamation.	Post mortem changes, apparent retrogression, doubtful on account of post mortem changes. Card 1066.
20 days.....	Small number of follicles, loosely arranged.....		Considerable connective tissue in places, loose areolar, blood spaces, smooth muscle.	Low cuboidal.....	Regression. Card 1067.
20-day control.....	Follicles more closely packed.....		Less stroma.....	High cuboidal to columnar.	Marked differences between this and no. 14, for which it is the control. Card 1068.
22 days.....	Very large follicles closely packed, invading pit; evidence of former erosion of cartilage.		Moderate connective tissue, smooth muscle.	Mostly low, some completely reduced, others high, a few columnar.	Distinct regression of a marked hyperplasia. Card 1063.
22-day control.....	Smaller and less compactly arranged follicles.....		Much areolar tissue.....	High throughout, cuboidal to high columnar.	Hyperplasia; moderately different from no. 10, for which this is control.
24-day control.....	Several masses of rather loosely arranged follicles of varying sizes and shapes and quite well separated; no infiltration of cartilage or muscle.		Much connective tissue in some parts, others loose areolar.	High, cuboidal, much of it columnar.	Moderate hyperplasia. Lot 2053B; card 1127.

24 days.....	Much less thyroid, more widely separated, and larger follicles.	More connective tissue in places, others loose areolar.	All follicles filled with colloid.	Low, most of it completely reduced.	Decided regression. Lot 2053B; card 1126.
26-day control.....	Fairly large thyroid mass of varying follicles; some very closely packed; others widely separated.	Much connective tissue in parts, loose areolar in others.	Small amount.....	High; cubical to columnar.	Moderate hyperplasia. Lot 2053B; card 1129.
26 days.....	Much less thyroid, more uniform; larger and widely separated follicles.	Much connective tissue, loose areolar.	Large amount.....	Low, cuboidal to complete reduction.	Very positive regression. Lot 2053B; card 1128.
27 days.....	Thyroid mass small, scattered follicles.	Considerable connective tissue, much loose areolar.	.....do.....	Low, cuboidal.....	Distinct regression. Lot 2053B; card 1130.
29-day control, 2 fish red floors.....	Large number of good-sized follicles, some loosely arranged, others compact; very little infiltration of muscle.	Moderate connective tissue.	Moderate amount.....	High, some columnar.....	Moderately advanced hyperplasia; controls for no. 41. Lot 2053B; cards 1134A and 1134B.
29 days, 2 fish, red floor.....	Smaller number of larger follicles more loosely arranged.	Much loose areolar tissue.	Much colloid.....	Low; very low cuboidal to complete reduction.	Decided regression. Lot 2053B; cards 1133A and 1133B.
Control for 30-day fish.....	Large number of follicles, varying in size and shape, infiltrating muscle.	Large amount separating follicles, many smooth in ucle strands.	Small amount.....	High, cuboidal to columnar.	Moderately advanced hyperplasia. Lot 2053B; card 1132.
30 days.....	Thyroid much smaller; more uniformly large follicles.	Less connective tissue, more loose areolar.	Much colloid.....	Low, most of it reduced	Marked regression. Lot 2053B; card 1131.
2 days, tumor.....	Tumors; pit and throat reduced 1 mm. in diameter; much papilliform epithelial invagination.	Very little.....	Very little.....	High, mostly high columnar.	Also received 2.75 mg. HgCl ₂ in stomach one day before death; no microscopic evidence of reduction. Card 1135.
3 days, tumor.....	A large number of large follicles, more compact near pharyngeal floor.	Considerable connective tissue.	Much colloid.....	Low; high in only a few follicles.	3 days in Hg 1 to 5 cc.000, then in standard Hg 1 to 300.000; killed by 3 1/2 hours exposure, striking reduction. Card 1136; fig. 106.
Do.....	Large mass, closely packed follicles, much epithelial invagination; infiltration, muscle and cartilage.	Small.....	Moderate.....	High, much of it columnar.	Also 2.75 mg. HgCl ₂ in stomach 2 days before death; no apparent reduction. Card 1137.
4 days, tumor.....	Tumor reduced from 24 mm. to 18 mm. in diameter; very cystic; large cysts surrounded by compact thyroid containing many small follicles.	Moderate connective tissue.	Little colloid.....	Mostly high; some shows reduction.	Beginning reduction not marked histologically, but none evident microscopically. Card 1138.
7 days, tumor.....	Tumor reduced in size; large follicles, many irregular and with branching epithelial ingrowths around these; more compact smaller follicles, others more scattered; follicles smaller.	Large amount of connective tissue between masses of thyroid, loose areolar tissue.	Smaller, more scattered follicles filled with colloid, others not.	Variable; in the colloid filled follicles low, in others high.	Distinct reduction marked in some parts of tumor, more in others. Cards 1139 and 1140.
7 days, small tumor.....	Microscopic evidence of reduction; extremely large follicles, surrounded by layer of smaller ones; some have ingrowing epithelial papillae.	Moderate connective tissue, some smooth muscle.	Much colloid.....	Uniformly low, moderately high in only a few follicles.	Marked reduction; same lot as no. 27. Card 1141.

TABLE XII.—MERCURY AS $HgCl_2$, CONTINUOUS FLOW; Hg 1 TO 5,000,000—Continued.

[All domesticated brook trout clinically clean unless otherwise stated.]

Duration of mercury treatment.	Histological condition of thyroid gland.				Diagnosis and general remarks.
	Distribution.	Infiltration.	Stroma.	Stainable colloid.	Epithelium.
7 days, tumor.....	Tumor reduced in size; many large irregular follicles, some with papilliform ingrowths.		Small amount.....	Much colloid.....	High, mostly cuboidal, some columnar; many follicles at periphery of tumor mass have reduced epithelium.
9 days, tumor.....	Throat tumor which has become smaller; closely packed follicles and some epithelial masses; invasion of muscle and cartilage.		Much connective tissue, some smooth muscle, some hemorrhage.	Many large colloid; containing follicles.	Much low epithelium, considerable desquamation; probably postmortem changes.
11 days, tumor.....	Tumor reduced $\frac{1}{4}$ mm.; numerous, rather loosely packed, large follicles, much thinning out at periphery of mass, largest follicles in center of mass; no evident infiltration.		Considerable connective tissue and loose areolar.	Much colloid.....	Very low; mostly complete reduction, a few cuboidal.
Do.....	Numerous large follicles loosely packed, some very large like colloid cysts.		Much loose areolar, some connective tissue.	.....do.....	Very low.....
18 days, tumor.....	Tumor little if any reduced in size; groups of closely packed follicles separated by loose areolar and connective tissue.		Much connective tissue, loose areolar; hemorrhages, leucocytic infiltration and cyst-like spaces.	Considerable colloid....	Mostly low, cuboidal; a few high, some columnar.
40 days, tumor.....	$\frac{7}{8}$ mm. tumor nearly gone, consists in part of large and small follicles loosely arranged, others more compact; tumor much thinned out at periphery; small atrophied follicles.		Much connective tissue, especially at periphery.	Much colloid.....	Mostly very low; a few follicles high to low cuboidal.
					Also received 2.75 mg. $HgCl_2$ in stomach on first day; slight reduction, but distinct, as shown by thinning out of thyroid at periphery. Card 1142.
					Marked reduction of tumor. Card 1051.
					Marked reduction. Lot 1937; card 1143.
					Great reduction. Lot 1937; card 1144; fig. 108.
					Much thinning out of tumor from within, islands of original tumor remaining; apparent marked reduction. Card 1065; fig. 107.
					Marked regression. Card 1145. A most clinically clean.

TABLE XIII.—MERCURY, INTERMITTENT AS Hg_2Cl_2 ; Hg_1 TO 38,600,000, TWICE DAILY, TO INFINITE DILUTION IN FOUR HOURS.
[Domesticated landlocked salmon and brook trout.]

Duration of treatment.	Histological condition of thyroid gland.				Diagnosis and general remarks.
	Distribution. Infiltration.	Stroma.	Stainable colloid.	Epithelium.	
15 days.....	Pharyngeal spaces filled with loosely packed follicles of varying size, some very large and some very small, very few of irregular outline; some invasion of muscle.	Much loose areolar tissue between the follicles.	Much; all follicles contain it.	Mostly low cuboidal.	L. salmon, clinically clean; no marked evidence of regression; moderate hyperplasia, if anything retrograding. Lot 1950; card 2020A.
Do.....	Isolated masses of mostly small follicles separated from each other by large hemorrhagic areas; thinning out of follicles under pharyngeal floor; some large follicles and a few small colloid cysts; some invasion of muscle and cartilage.	Much loose areolar tissue in places; numerous blood spaces and clots undergoing organization.	Much.....	Low throughout; some completely reduced, others low cuboidal.	L. salmon, clinically clean; retrograding hyperplasia. Lot 1950; card 2020B.
Do.....	Pharyngeal spaces completely filled with solidly packed columns and masses of epithelium with only an occasional distinct alveolus in some parts and scattered alveoli in others, widely separated by packed epithelium; invasion of muscle and bone.	Relatively small; much blood in alveoli and a few blood spaces.	Only an occasional follicle contains colloid.	High, columnar in alveoli.	Brook trout; large throat tumor; no regression; has histologic appearance of malignancy. Lot 2215; card 2021A.
15-day control.....	Pharyngeal spaces partly filled with typical alveoli, but varying greatly in size; no invasion of cartilage bone or muscle; occasional small cyst.	Very moderate connective tissue.	Much.....	Mostly low cuboidal.	L. salmon; clinically clean; control for no. 2; apparent regression of moderate hyperplasia. Lot 1950; card 2022.
Do.....	Mixed tumor, in part closely packed epithelial cords; in part adenomatous large papilliform ingrowths near surface; scattered colloid containing alveoli.	Much connective tissue, especially at periphery and under floor of pharynx.	Very little.....	High, cuboidal to columnar, low in some parts.	Brook trout; pit tumor; some regression; adenoma, mixed tumor. Lot 2215; card 2023.
15 days.....	Pharyngeal spaces filled with spherical follicles, part of which are small and closely packed and part large; many very large and filled with colloid.	Very little.....	Much, especially in larger follicles.	High in smallest follicles, low in larger ones.	Brook trout; tumor, mouth and pit, in microscopic evidence of diminution; apparent regression. Lot 2215; card 2021B.
31 days.....	Relatively small masses of loosely packed follicles, well separated, of varying size, spherical in outline.	Loose areolar tissue...	All follicles filled.....	Uniformly low.....	L. salmon, clinically clean; very moderate hyperplasia; apparently distinctly retrograding. Lot 1950; card 2026A.
Do.....	Pharyngeal spaces moderately filled with closely packed follicles, some of which are very small.	Very little connective tissue.	Moderate, about one-half of follicles filled.	Varying from low to high cuboidal, mostly low.	L. salmon, clinically clean; moderate hyperplasia; retrograding. Lot 1950; card 2026B.

TABLE XIII.—MERCURY, INTERMITTENT AS Hg_2Cl_2 ; Hg 1 TO 38,600,000, TWICE DAILY, TO INFINITE DILUTION IN FOUR HOURS—Contd.
(Domesticated landlocked salmon and brook trout.)

Duration of treatment.	Histological condition of thyroid gland.					Diagnosis and general remarks.
	Distribution.	Infiltration.	Stroma.	Stainable colloid.	Epithelium.	
31 days.....	Pharyngeal spaces filled with closely packed epithelial cords and masses; relatively few follicles; looks like carcinoma invasion of surroundings; invasion of gill arches.		Almost none.....	Very little.....	High, especially in follicles, high columnar.	Brook trout ♀; throat and pit tumor (malignant?); no microscopic evidence of change; apparently no regression. Lot 2215; card 2027.
Do.....	Mixed tumor; mostly closely packed columns, whorls and masses of epithelium, inclosing largemass of adenomatous growth, atrophied follicles at periphery; invasion of all structures.		Connective fibrous, mostly at periphery.	None.....	High, especially in adenomatous portions.	Brook trout ♀; throat and pit tumor; no microscopic evidence of change; mixed adenoma and carcinoma(?); no retrogression. Lot 2215; card 2028.
Do.....	Small masses, loosely packed follicles.....		Loose areolar.....	Considerable.....	Low.....	L. salmon ♂, clinically clean; moderate hyperplasia; retrograding. Lot 1950; card 2029A.
Do.....	Small loosely packed follicles.....		.....do.....	Much.....	.....do.....	L. salmon ♂; clinically clean; retrograding hyperplasia. Lot 1950; card 2029B.
Do.....	Pharyngeal spaces filled with closely packed follicles of uniform size; invasion of cartilage.		Very slight.....	Moderate amount.....	Moderately high.....	L. salmon, clinically clean; well-advanced hyperplasia; no definite evidence of regression. Lot 1950; card 2030.
43 days.....	Loosely packed masses of small colloid filled follicles; evidence of former invasion of muscle.		Much loose areolar.....	Much.....	Low.....	L. salmon ♂, clinically clean; distinct regression of a moderately advanced hyperplasia. Lot 1950; card 2044.
Do.....	Pharyngeal spaces filled with very closely packed small follicles with a scattering of larger follicles; invasion of cartilage.		Very little.....	Very little.....	Low to high cuboidal.	L. salmon ♀, clinically clean; marked hyperplasia, but little evidence of regression. Lot 1950; card 2045A.
Do.....	Spaces filled with moderately closely packed follicles of average size; many follicles widely separated.		Much loose areolar.....	Moderate.....	.....do.....	L. salmon ♀, clinically clean; well advanced hyperplasia undergoing regression. Lot 1950; card 2045B.
Do.....	Very closely packed epithelium, looks like carcinoma; invasion of cartilage and muscle; areas of adenoma, also of colloid cyst and large colloid filled follicles.		Very slight.....	None, except in definite follicles and cysts.	High; low in many distinct follicles.	Brook trout ♀; throat and mouth tumor beginning resolution of parts of mixed tumor (adenoma and carcinoma?). Lot 2215; card 2046.

TABLE XIV.—ARSENIC AS As_2O_3 , CONTINUOUS FLOW; AS 1 TO 300,000.

[Domesticated landlocked salmon and brook trout.]

Duration of treatment.	Histological condition of thyroid gland.					Diagnosis and general remarks.
	Distribution.	Infiltration.	Stroma.	Stainable colloid.	Epithelium.	
14½ days.....	Pharyngeal spaces partly filled by follicles of varying size and shape, some compact, others loosely arranged, many separating spaces of areolar tissue; apparent disappearance of follicles under pharyngeal floor; some invasion of cartilage.		Much loose areolar tissue; many blood spaces.	Moderate.....	Mostly low cuboidal, but varying in height; some high cuboidal, some completely reduced.	Originally clinically clean; moderate hyperplasia, undegenerating regression. Brook trout, lot 2081; card 2034B.
Do.....	Layer under pharyngeal floor; flattened out follicles between fibrous tissue, which has largely replaced the thyroid at this point; the visible tumor portion is also almost entirely replaced by connective tissue; the center growth papilliform in type, separated from surrounding tissue by dense fibrous tissue which has apparently replaced former thyroid.		Much fibrous connective tissue about peripheral portions, also invading main tumor mass.	Considerable colloid; some large masses.	High columnar in papilliform part of tumor completely reduced where follicles have been compressed by connective tissue.	Brook trout ♀; small throat tumor, the tumor much smaller, hardly visible; distinct regression. Lot 2081; card 2033B.
Do.....	Pharyngeal spaces filled with a very variable thyroid mass, containing islands of papilliform follicles surrounded by typical follicles and masses of new formed connective tissue embedding compressed follicles; periphery of tumor largely replaced by connective tissue; infiltration of muscle and cartilage.		Large amount fibrous connective tissue.	Considerable; more than in no. 2.	High in papilliform portion, but evidence here of reduction; low in other portions.	Brook trout ♂; fair sized throat and mouth tumor; mouth tumor disappeared, throat about one-half of original size; distinct regression. Lot 2034; card 2033A.
Do.....	Pharyngeal spaces partly filled by a variable thyroid mass; some follicles small and closely packed; others large, separated by strands of muscle; no invasion of cartilage; not involving floor.		Moderate connective and loose areolar.	Moderate.....	Mostly low cuboidal..	L. salmon, originally clinically clean; moderate regression. Lot 2081; card 2034C.
22 days.....	Rather widely separated and loosely arranged small and large follicles scattered through pharyngeal spaces.		Much loose areolar tissue, separating groups of follicles.	Considerable.....	Very low throughout..	L. salmon, clinically clean; marked regression. Lot 2081; card 2037.
Do.....	Islands of papilliform growths walled off by large masses of new formed connective tissue with scattered follicles.		Much fibrous connective tissue, apparently replacing former thyroid mass, especially in gill region.	Small amount in some sections, large amount in others.	High in papilliform portion, low in isolated follicles.	Brook trout; originally small throat tumor at beginning of experiment; tumor has disappeared; only macroscopic evidence left is red floor; marked regression. Lot 2034; card 2036; fig. 109.
Do.....	Pharyngeal spaces only partly occupied by thyroid follicles varying in size and arrangement from loosely to closely packed large and small follicles.		Considerable loose areolar.	Moderate.....	Variable, mostly low; a few scattered follicles contain high.	L. salmon, clinically clean; distinct evidence of regression, but not as well marked. Lot 2081; card 2038.

TABLE XIV.—ARSENIC AS As_2O_3 , CONTINUOUS FLOW; AS 1 TO 300,000—Continued.
[Domesticated landlocked salmon and brook trout.]

Duration of treatment.	Histological condition of thyroid gland.					Diagnosis and general remarks.
	Distribution.	Infiltration.	Stroma.	Stainable colloid.	Epithelium.	
14-day control.....	Pharyngeal spaces filled with thyroid mass, divided partly by connective tissue into several masses of somewhat different character, some ramifying papilliform, others large, and small follicles, invading bone and muscle.		Considerable connective tissue in some parts.	Moderate in some portions, entirely absent in others.	High throughout; highest in papilliform portions.	Control. Lot 2034 C; throat tumor, brook trout, growing mixed tumor in part adenomatous, in others goiter. Lot 2034; card 2032.
14½ days.....	Pharyngeal spaces only partly filled by varying densely and loosely arranged small and large follicles; some invasion of cartilage.		Connective and loose areolar tissue; a number of blood-filled spaces.	Very little.....	Varies from low to moderately high.	L. salmon, clinically clean; hyperplasia moderate, not definitely retrograding. Lot 2031; card 2034B.
22 days.....	Pharyngeal spaces partly filled with more or less closely packed follicles of varying size; invasion of muscle; some follicles, apparently atrophic.		Considerable connective and loose areolar tissue.	Large amount of colloid; most follicles filled with it.	Epithelium uniformly low, lowest in large follicles.	L. salmon, clinically clean; moderate hyperplasia, apparently retrograding. Lot 2031; card 2039.
22 days.....	Pharyngeal spaces partly filled with more or less loosely packed follicles, some small, others large; apparent atrophy and thinning out in many places under pharyngeal floor; thyroid tissue has largely disappeared, isolated follicles only being included in a dense mass of new-formed connective tissue, part of the thyroid of the papilliform type shows coalescence of follicles and a resumption of the typical colloid follicular arrangement.		Much new-formed connective tissue, especially replacing the peripheral portions of original tumor, included in this occasional follicle.	Much colloid.....	Low, except in papilliform portion in which it is high cuboidal and apparently undergoing reduction.	Brook trout; small throat tumor at beginning of treatment; tumor has entirely disappeared; marked regression. Lot 2034; card 2040.
Do.....	Center of mass papilliform, changing to colloid containing follicles; at periphery large and small follicles separated by dense connective tissue; invasion of muscle and cartilage.		Much connective tissue, especially at periphery and under pharyngeal floor.	A large amount.....	Low, except in papilliform portion where it is also undergoing reduction.	Brook trout; originally medium-sized throat tumor, at end of treatment barely visible, much reduced in size; marked regression. Lot 2034; card 2041.

TRANSMISSION OF THYROID DISEASE TO MAMMALS.

DOGS.

In June, 1910, a dog obtained in Buffalo, and her litter of six young, were taken to the Craig Brook station in Maine. They were placed in an inclosure near the fish ponds and fed liver. They were immediately given to drink constantly water from pond 10, and beginning with August 20 a pan of mud from the bottom of pond 10 with pond-10 water supernatant was supplied to them, the mud and water kept constantly renewed. The animals not only drank the supernatant water but consumed the mud in quantity. Seventeen days after the mud was first placed at their disposal all the puppies were found to have palpable thyroid enlargements, besides greatly enlarged cervical lymph nodes. This result was briefly reported at the Second International Cancer Congress at Paris in 1910.

The food of the puppies was changed to cereal, and upon examination late in November, 1910, all the enlargements had markedly decreased. Two of the animals, dogs 14 and 15, were shipped to Buffalo in December and killed.

Section of the thyroid gland of dog 14, under the microscope presents an appearance of the tissue easily discernible as normal. There is some variation in the size of the follicles. The epithelium is flattened, the majority of the follicles filled with stainable colloid. There are no evidences of hyperemia. Under high power the epithelium is uniform in size, flattened, the protoplasm stains diffusely with hematoxylin, the nuclei stain deeply, the long axes in the circumference of the lumen. There are no changes in the stroma.

Section of the thyroid of dog 15 shows a remarkable condition of the tissue. There is but the slightest suggestion of follicular structure in the section. (See fig. 113.) The entire tissue is made up of solid masses of epithelial cells, with deeply staining nuclei. There is absolutely no trace of colloid in any portion of the section. Compared with dog 14 the epithelial cells and their nuclei are distinctly enlarged. The nuclei stain deeply. They vary in size and at some portions of the section are vesicular. The protoplasm stains diffusely with nuclear stain and is distinctly increased in amount. Under high power the outlines of the follicles can be traced by capillaries. The entire alveolar space is filled with irregularly shaped epithelial cells lying somewhat loosely packed in some regions, more compactly in others. In the more open portions of the section a condition suggesting papillary projections into the alveoli of the lumen may be made out. The nuclei are vesicular. Occasional karyokinetic figures are found. We have here intensive proliferation of the epithelium, with complete disappearance of the colloid. Marked parenchymatous struma.

The remaining dogs of this lot were later shipped to Buffalo, and, at the last examination, made in July, 1911, no palpable thyroid enlargement was present. Thyroid regression influenced by the change from a high animal protein to low vegetable protein may be inferred.

A female brown spaniel (dog 24) obtained in Washington, D. C., was shipped to the Craig Brook station in the fall of 1910. On November 30 there was no palpable

thyroid enlargement. A bag of pond-10 mud was now placed in a pail, which was filled with Craig Brook water and placed in the kennel. The mud was not renewed, but fresh water was poured over it from time to time. The dog was fed a meat diet. July 5, 1911, the right thyroid gland was found enlarged nearly to the size of a small hen egg. The left gland was palpable but not evidently enlarged. During the next year pond-10 mud and water was supplied to the dog, and on July 1, 1912, she was in good condition, with both thyroid lobes decidedly enlarged. The left lobe was removed and found to weigh 19.3 grams, its dimensions being 5.5 by 3.5 by 2.75-centimeters. There was no control for this dog.

Under the microscope the thyroid of dog 24 presents follicles of great size filled with stainable colloid, protruding into which are many bud-like processes. The epithelium is columnar in the larger alveoli, the flattened nuclei stain deeply, are oval or spherical, the protoplasm also taking the nuclear stain. The bud-like processes are caused by infoldings of the walls of the alveoli covered with columnar epithelium. The whole presents the appearance of a gland which has been in a state of active hyperplasia, but is at present a colloid gland.

The feeding of these dogs was intended as a preliminary informal trial and was not controlled. Having indicated the probability of positive results in an important field, more accurate experiments were begun with other young dogs.

A bitch with a litter of five pups was obtained from the District of Columbia, a nongoitrous region. These were shipped to the Craig Brook station, in October, 1910. The mother and two pups were supplied until the following summer with a pan of mud from pond 10 holding pond-10 water supernatant, both kept frequently renewed. The three remaining pups were held as controls and received mud and water from Craig Brook directly, unconnected with fish-cultural conditions. The food for all was shredded wheat scrap and milk until December, when it was changed to dog biscuit with occasional cooked liver, and this continued until spring, when it was again changed to cereal. The two lots of dogs were separately confined in kennels indoors and were exercised and let loose only under proper restrictions.

On palpation in July, 1911, no thyroid enlargement could be detected in any of them. This experiment was now abandoned and a new one instituted with scrapings from the inside of unpainted wooden fish troughs (no. 93), which had long been used to hold domesticated trout and in which thyroid tumors were constantly produced in such trout. (Table III.)

The three pups formerly used as controls were now given to drink Craig Brook water from a pail containing the fish-trough scrapings suspended in a cheesecloth bag. The material was kept cold by standing it continuously in a trough of flowing cold water. A portion of the clear water from the pail was supplied to the dogs each day. The mother and the two pups which had formerly received pond-10 mud and water for several months were now used as controls to the experiment with scrapings. They received water taken from the same pail and boiled. All the dogs were fed liver, cooked and uncooked. The experiment began August 1, 1911, and in January, 1912, was terminated

and the dogs shipped to Buffalo. The three which received unboiled water from the scrapings were in poor condition and one of them died just before shipment.

Of these three puppies (dogs 16, 17, and 22) the one which died spontaneously (dog 16) and one of the others (dog 17), both had plainly palpable thyroids, from one-third to one-half larger than normal, in gross section, firm and red, approaching spherical instead of normal fusiform shape. In both instances the two lobes were about equally enlarged. The section of the thyroid of dog 16 shows outspoken evidence of hyperplasia. There are no spherical or oval follicles, all the open spaces in the tissue are of irregular shape due to pronounced papillary projections of the epithelial structure into their lumina. Colloid is present in some of the follicles. The greater area of the section is composed of small irregularly shaped follicles many of which contain no colloid; others partly filled with poorly stainable colloid. Under high power the epithelium is found to be high columnar, the nuclei enlarged and often vesicular with one or more nucleoli. There is distinct enlargement of the capillaries in the stroma. In many areas the proliferation has been so intense as to practically fill the alveolar spaces with compact masses of epithelium. Occasional deposits of brown hematogenous pigment are found within the alveoli. There is distinct variability in the size of the nuclei, occasional ones being greatly enlarged and vesicular. Karyokinetic figures are rare. Diagnosis: Marked hyperplasia with great reduction of colloid. (Fig. 111, dog 17.) The histological description of dog 16 applies in every way to dog 17. (Fig. 112.) Diagnosis: Marked hyperplasia with great reduction of colloid.

Puppy 22 was not operated until March 18, when the right thyroid was removed. It was about normal in size, measuring 35 by 17 by 12 millimeters, and weighed 3 grams. The dog weighed 7.71 kilograms. The third puppy (dog 22) presents a histological condition in the thyroid similar to dogs 16 and 17. The epithelium is high columnar, the alveoli of irregular shape, due to plentiful papilliform processes into the lumen. The larger alveoli contain poorly staining colloid. There is some variation in the different portions of the section chosen for study in this case. One portion somewhat remote from the more intensely hyperplastic region presents a somewhat more normal appearance. The alveoli retain a more oval appearance, the papillary processes are smaller. More colloid is present. The epithelium is, however, high columnar. The nuclei stain poorly and more homogeneously than in the other regions where they are of a more vesicular type. Diagnosis: Marked hyperplasia. (Fig. 115.)

None of the controls (mother and two pups, dogs 19, 20, and 21) had palpable thyroid enlargements. They were all operated in March, and the left thyroid of each removed. These left lobes were normal in size and appearance and similar in size to the right lobes. The mother dog (19) weighed 10.9 kilograms, the left lobe 2.4 grams; one of the pups (dog 21) weighed 8.6 kilograms, its left lobe 2.05 grams, measuring 32 by 17 by 9 millimeters. The other puppy (dog 20, fig. 114) weighed 10 kilograms; its left lobe 6.4 grams, and measured 47 by 22 by 12 millimeters. Histological examination of the thyroid of the mother (dog 19) shows normal thyroid structure for a dog of this age. (Fig. 116.)

The puppy (dog 21) presents a thyroid structure which may be considered normal for a young dog. The alveoli are less spherical and oval, varying in size, filled with stainable colloid. The epithelium is flattened. There are some areas in the thyroid structure in which a slight tendency to budding of the epithelium with a change to columnar may be observed and there are some areas in which there appears to be a somewhat richer stroma than usual. It is, however, only an increase in amount of connective tissue without any evidence of changes in staining characteristics of the cells. As this puppy received pond-10 mud and water for several months previous to the final experiment, it is possible that the very slight changes here noted may be evidence of the first beginnings of a change induced during that period. Diagnosis: Normal thyroid of puppy. (Fig. 110.)

Section of the left lobe of the thyroid of dog 20 shows follicles of varying size, the oval and spherical type predominating, but some follicles in which there is evidence of beginning bud formation. The lining epithelium of the more simple follicles is flat. The follicles are filled with stainable colloid. In the somewhat more irregular follicles the epithelium forming the budlike projections into the alveoli is cubical. The nuclei are stained deeply and are spherical or oval. The details of the nuclei can not be made out. Intensely stained. There is some slight thickening of the septa here and there through the thyroid tissue. No evidence of hyperemia, no other change except the slight budding. (Fig. 114.) The thyroid tissue is mostly normal for a young dog; slight evidences indicating the beginning of hyperplasia. As this dog had previously received pond-10 mud and water, as had dog 21, slight evidences of hyperplasia may be due to this previous stage of the experiment. Diagnosis: Areas of slight hyperplasia.

In the same way and beginning at the same time (Aug. 1) as in the preceding experiment, a young bull terrier (dog 18) was given to drink water in which was suspended scrapings from another and old fish trough (no. 9 of old hatchery). The water, however, was kept in the kennel and the dog allowed to drink at will. The temperature varied with the weather. In the winter the room was heated somewhat to prevent freezing, but seldom rose above 45° F., and was often near the freezing point. The control was dog 19, which received the scrapings water after boiling. Neither had thyroid enlargement at the beginning of the experiment. The food was liver and dog biscuit for both. The bull terrier, after receiving for six months water from the pail in which were suspended the scrapings, showed a marked emaciation, muscular weakness, and a staggering gait. The thyroid was readily palpable. The dog was killed and both lobes found distinctly enlarged, the left lobe being about one-quarter larger than the right and measuring 54 by 28 by 26 millimeters, and both very vascular.

Under the microscope the thyroid gland shows extensive pathological change. The tissue is for the most part made up of a solid adenomatous structure with irregular and narrow spaces representing preexisting vesicles. Under low power whole fields of almost solid compact adenomatous tissue are found. In the irregular clefts and spaces in the more open portions of the tissue, complex and marked papillary processes covered with high columnar epithelium characterize the tissue. This change may be said to be more constant in the peripheral portions of the section of the thyroid tissue. (Fig.

118.) Passing toward the center of the lobe there are marked degenerative processes in the tissue. The clefts become fewer in number, the epithelium stains less irregularly than before, the irregular alveolar openings are fewer, and the whole tissue is composed of a confusion of cells with just a suggestion of the previous clefts representing the old alveoli (fig. 117), which in this region appear to be filled by desquamated and rather poorly staining cells.

At the very center of the lobe the evidences of degeneration are more intense. One finds masses of cell complexes, deeply staining and homogeneous protoplasm. The cell boundaries are destroyed, the nuclei, although still staining deeply, are embedded in the protoplasmic structure with only the most ill-defined suggestion of cell boundaries to the protoplasm. (Fig. 119.) At the peripheral portion of the lobe where the papillary adenomatous type of tissue is well preserved, no evidences of degeneration are to be found. One finds in various places in the capsule evident invasion of this structure. The capsule is thick, composed of fibrous connective tissue with small, deeply stained connective tissue nuclei. In the dense fibrous structures of this capsule at various points definite alveoli lined with high columnar epithelium are found, extending in some instances to the outermost limit of the thick capsule. Under high power the epithelium of these alveoli and the capsule is found to be high columnar, most of the nuclei staining deeply and homogeneously, but here and there are vesicular nuclei with one or more nucleoli. The epithelium is in some of these alveoli several layers thick; the protoplasm stains deeply with a cytoplasmic stain. Some of the larger nests of cells in the capsule have almost lost their alveolar structure and formed more or less compact islands of cells, with nuclei varying in size, many of them vesicular.

In the margins of such a complex of cells one finds direct invasion of the dense connective tissue structure of the capsule, there being no stroma between the vesicles and no delimiting membrane to them. In fact, individual cells can be found invading the connective tissue fibers. Occasional karyokinetic figures are found and about the larger masses of cells described there are evidences of expansive growth in the arrangement of the immediate encircling fibers of the capsular structure.

Under high power the outer zone of adenomatous proliferation shows great variability in the nuclei of the cells, most of them being vesicular, with one or two nucleoli. They vary in form from elongate to oval and spherical, mostly oval. The smaller nuclei stain more homogeneously than the larger ones, the epithelium covering the papillary projections is high columnar, the protoplasm stains diffusely, and occasional cells are found in this region in which a swollen and cloudy appearance of the protoplasm indicates the first evidence of degeneration. The stroma of the papillae is not well developed. The capillaries are plentiful but do not form a prominent part of the picture.

Approaching the center of the lobe, large irregular clefts, made up by the papillary projections, are less in evidence and large areas are found in which the epithelium presents peculiar forms and a swollen, cloudy appearance of the protoplasm. The cells are of the most bizarre form and shape, often are spindle shaped, and what has previously been the alveolar spaces in the cells are filled with closely packed, desquamated epithelium. The nuclei here still stain well, are vesicular in character, and vary greatly

in size and form. At the center of the lobule where the degenerative changes are most outspoken are found large areas of desquamated cells with cloudy protoplasm, taking the stain deeply. The cell boundaries are not sharply defined, the nuclei generally smaller than in the preceding area, of varying size and deeply stained. Diagnosis: Diffuse hyperplasia of the thyroid gland with degenerative changes at the center and invasion of the capsule at the periphery.

RATS.

In 1910 and 1911 a prolonged attempt was made to affect the thyroid of rats by giving them water to drink from the fish ponds in which the disease was endemic. A barrel of water from pond 10 of the Craig Brook station and a quantity of mud from the same pond were shipped to Buffalo and kept in cold storage. A series of experiments were begun with young rats obtained from Granby, Mass. Each experimental lot consisted of 10 rats. The food was a mixture of corn, oats, sunflower seeds, and dog biscuit. The mud and water was administered daily to the separate lots as follows:

1. Trout-pond mud; small quantities.
2. Trout-pond mud; large quantities.
3. Trout-pond water.
4. Craig Brook water.
5. Trout-pond mud; cooked.
6. Trout-pond water; boiled.
7. Trout-pond water, injected subcutaneously, followed by mud and water feeding.

The feeding of the mud, water, etc., was continued with the same individuals for a period of about six months. A few were killed from time to time during this period for examination of the thyroid. Neither in these nor in those remaining at the close of the experiment were there any thyroid enlargements or any microscopic condition differing materially from the controls.

In the light of Bircher's subsequent observations there are several reasons why these experiments might have failed. Bircher gives the following reasons why water may lose its goiter-producing qualities: (a) Water kept under conditions different from those of its origin for days or weeks; (b) water which before use has been continually shaken or has undergone a long trip by rail; (c) water to which small amounts of chemical agents have been added; (d) that the agent is more active in the water in the summer months and that the source frequently loses its activity in the winter. Three of these reasons bear on the possible negative nature of the above experiments, and as they are all made with water taken from ponds in which the agent is present in dilute form, it is quite clear that the length of time was not sufficiently great to produce positive results. These experiments must therefore be repeated with the animals at the source of water supply and continued over a period not less than 18 months.

The pond water and mud having failed to produce definite changes in rats during six months under the experimental conditions, a quantity of scrapings from one of the wooden fish troughs (no. 102), in which thyroid tumors were constantly developed, was

brought to Buffalo. The material was kept cold in a thermos bottle during transportation, and on arrival was placed in a cheesecloth bag and immersed in a glass jar of water and kept in the refrigerator. Preliminary trials were made by using this as drinking water for rats on a raw-meat diet. No marked changes occurred during the first month, but at four months one of six rats showed a great enlargement of the thyroid, and nearly all had marked pathological changes consisting of reduction of colloid, increase in height of epithelium, congestion and presence of numerous mitoses. A carefully controlled experiment was now begun with the scrapings water, the diet being changed to dog biscuit and salted lake herrings, the latter for the purpose of increasing thirst and consumption of the water. Twenty-four rats received the scrapings water, and 12 control rats received boiled water from the same source. This experiment is still in progress. The results at the close of this record indicate that the rat thyroids undergo changes similar to those in the dogs, but of a less intensive nature. Figure 120 shows a normal thyroid of the rat from a control; figure 121, hypoplastic thyroid from a rat from this experiment.

In considering the above experiments, from which it will be seen that a definite enlargement with diffuse proliferation of the thyroid gland may be produced in dogs in a period of five months by giving them to drink the water in which suspended scrapings from wooden troughs in which the fish kept had regularly developed carcinoma of the thyroid, and that the control dogs receiving the same water boiled have in the same time developed no appreciable change in the thyroid gland, it naturally becomes important to determine what is the exact character of the change in the thyroid gland of the experimental dogs.

At the time, 1910, when the first experiments along these lines were made, we were not aware of the experiments of Bircher and of Wilms in the production of goiter in dogs and rats by giving them water to drink from goitrous wells. From the various publications of E. Bircher it will be seen that in his results obtained in rats (1911, b) he has produced, in periods varying from 9 to 18 months, distinct enlargement of the thyroid, with pathological changes which he divides into two classes, viz, nodular or adenomatous type and parenchymatous hyperplastic, mostly with degenerative processes. In the nodular hyperplastic form he has produced typical struma nodosa, which, as he points out, is a condition of the mammalian thyroid intimately associated with tumor formation. The parenchymatous hyperplastic type seems to be an expression of a more intensive action of the goiter water, and it is to this type that the changes we have produced in the thyroids of our experimental dogs more closely approximate. In dog 18, in which we have the most outspoken change, we find distinctly marked degenerative changes of the protoplasm in the center of the lobe. These changes give, at first glance, the impression of being due to poor fixation of the tissue or to post-mortem change.

Changes of a similar nature have been produced by de Quervain (1904) in the thyroid by the injections of toxic substances. De Quervain's studies indicate that the process is intravital, and for his tumor rats Bircher takes the same position. It is of great interest that Halsted, who originally (Welch, 1888) showed that by removing a part of

the thyroid of normal dogs, the remaining portion would become hyperplastic (1896), has recently (1913) repeated these experiments and now finds that when the present-day aseptic methods are employed, especially the careful sterilization of the skin with iodine, no compensatory hypertrophy results. Although not definitely expressing himself as to the cause of the hyperplasia which followed his original experiments, in the light of de Quervain's production of hyperplasia with the products of organisms, above referred to, Halsted recognizes the possibility that the hyperplasia in the older experiments may have been due to infection.

The experiments of Bircher indicate a very intimate relation between the experimental production of struma in rats and dogs and the etiology of tumors of the thyroid. The fact that he has produced nodular struma in rats, that struma nodosa is generally looked upon as the change from which neoplasms of the thyroid in mammals spring, that the other changes of the thyroid in his experimental rats present intensive parenchymatous hyperplastic degeneration, makes it clear that perhaps the concentration of the agent causing goiter and the method of its administration, the length of time in which it is permitted to work, or the intensity of its action may determine the character of the early changes of the thyroid in these experiments. The changes in our dogs have apparently developed more quickly and more intensely than those in the experiments made by Bircher. This would probably explain why our results have shown such diffuse and intensive changes in the thyroids of our affected dogs. Dog 18, the only adult dog so far exposed to the action of the agent in our experiments, presents outspoken degenerative changes at the center of the gland and evidences of infiltration of the capsule. The period of time covered by Bircher's experiments was much longer than those of our own.

We have reported briefly on a few experiments with rats, from which it is clear that hyperplastic changes in the thyroid may be induced in rats under conditions similar to those detailed in the experiments with the dogs. There are many other points of similarity between Bircher's experiments and ours. The agent is in both cases destroyed by boiling and it is not readily transported for a great distance. We have been unable to produce changes in the thyroid of rats with water transported from Maine to the institute in Buffalo. Our prompt and best results have, as with Bircher, been obtained by giving the water from the scrapings freshly to the animals on the ground where the agent is produced. We have not yet been able to carry out extensive filtration experiments, but have such experiments in progress and hope to report on them later.

Bircher, in his experiments, has compared the results obtained in the production of experimental struma in rats with the results obtained by de Quervain and argues therefrom that the agent of goiter as he finds it in Switzerland is probably a parasitic agent. He finds in filtration experiments with moderately fine Berkefeld bougies that intensive general degenerative changes of the nature of cretinism are produced by the residues scraped from the outside of the filters, and infers that possibly it is the toxic products of an organism which pass through the filter. These toxic products tend to produce struma and the unfilterable portions possibly contain the organism that tends to produce general constitutional disturbances of growth, i. e., cretinism. Our dog 18 showed general nutritional disturbances, loss of weight and strength, staggering gait. To deter-

mine whether or not extensive constitutional disturbances can be produced with the agent which we hold responsible for carcinoma of the thyroid in fish will require extensive experiments with young animals carried over a longer period of time than our experiments have thus far encompassed. It is quite clear from these experiments that there is a most intimate relation between the experimental production of goiter and the development of malignant disease of the thyroid in mammals. The infiltration of the capsule in dog 18 is extremely suggestive. Further experiments with older animals carried over a considerable period of time will be necessary before it can be definitely determined whether or not the agent responsible for carcinoma of the thyroid in trout is capable of producing infiltrating, possibly metastasising tumors in mammals. Bircher's experiments in producing nodular struma in rats makes the outlook in this direction promising.

The first attempts to produce experimental goiter in the lower animals by giving them to drink water from goitrous sources were undertaken by Klebs and H. Bircher (1883?) who, however, did not arrive at successful results. Carle in 1888 and Lustig in 1890 succeeded in producing in both dogs and horses, in regions free from goiter, enlargement of the thyroid as the result of giving them water from goitrous sources over a period of months. The most elaborate and carefully studied experiments are those by E. Bircher, jr., above referred to. Since his observations Répin (1911) and Breitner (1912) have carried out experiments and confirmed his results especially in rats, dogs, and monkeys, their experiments likewise extending over several months.

Dieterle, Hirschfeld, and Klinger (1913) have repeated the experiments of Bircher, Wilms, Répin, and others, and arrive at the following conclusions: That in regions in which goiter is endemic it is possible to produce goiter in rats by giving them copious amounts of water to drink. Their success ranges from 40 to 70 per cent. Second, the nature of the water which is used in a goitrous locality is without significance. The water may be either fresh or boiled, and goiter may be produced with water which at the point of its origin is not a goiter-producing water. Rats in a goiter-free locality in Zurich which were given goiter water from other localities did not at first develop goiter. Later, however, a few positive results were obtained, but it was felt that contact infection could not be excluded. Because it is possible to develop goiter in rats in goiter regions with water from goiter-free localities, they conclude that the primary character of the water is not the determining factor in the development of goiter. They point out that in goiter localities boiling the water does not protect experimental animals against the development of goiter, but that in goiter-free localities boiling the water destroys the goiter-producing character of such water. They conclude that this indicates that the etiologic agent of goiter must be occasionally transmitted through the water. These experiments conform with the work, as yet unpublished, of Landsteiner, Schlagenhauser and Wagner, and v. Jauregg, which will show that rats which were given nothing but boiled water from Vienna and kept in a peasant's house in the neighborhood of Rothenthurm in Judenburg, in Steiermark, in which all the inmates of the house were either goitrous or cretinic, developed goiter in a percentage equal to that obtained with rats, using the goitrous water of that locality, whereas attempts to produce goiter in rats in Vienna with the goiter water of Rothenthurm gave only negative results.

It would thus appear that water is not the exclusive carrier of the etiological agent of goiter, but the giving of large quantities of water to experimental animals in a goitrous region, favors the development of goiter when the agent may find entry in some other way. These observations tend to increase the significance of the finding of nematodes or other possible carriers in connection with the production of experimental goiter in animals.

McCarrison (1909) produced experimental goiter in human beings by giving them residues from the filtered water of Kashrote, where goiter prevails to the extent of 45 per cent of the total population. Experiments were carried out in the nongoitrous village of Barmis so controlled that they were provided with water for drinking, bathing, and other cleansing purposes from the Barmis spring, which is nongoiter producing, but which, as an added precaution, was boiled. Their diet was chiefly vegetable. Of 13 individuals who consumed the untreated residue of the goiter-producing water of Kashrote 4 developed a noticeable swelling of the thyroid gland, while 2 others showed an increase in size of the organ, demonstrable by measurement and evident to the touch. In three cases the enlargement was produced early, making its appearance on the thirteenth to the fourteenth day of the experiment. It was not great nor did it appear under the conditions of the experiment to be progressive. Of eight individuals who under the same conditions consumed the boiled residue of the goiter-producing water of Kashrote none developed any swelling of the thyroid gland, and this although three were individuals peculiarly likely to respond to goitrous influences. McCarrison therefore concluded (1) that goiter is due to matter in suspension in the water; (2) that goiter is not due to the mineral but to the living part of the suspended matter; in other words, to a living organism of the disease; (3) that the incubation period of experimentally produced goiter is 13 to 15 days.

An experiment of similar import is reported by Breitner (1912) which relates to a family of father, mother, and seven children who, coming from a goiter-free region, drank the water from a goitrous well with the result that all nine individuals developed a great increase in the circumference of the neck with palpable tumors. Upon the advice of Breitner they boiled the water from this source and after a period of four weeks a distinct diminution of the thyroid tumors occurred, but later they disregarded this advice with the result that the thyroid enlargement again progressed. From this well Breitner carried out experiments with rats with the result that in 19 rats 2 developed large visible struma, 2 thyroids two and one-half times as large as normal, and 4 showed microscopic diffuse enlargement of the thyroid, whereas 20 controls showed no enlargement.

The literature contains many accounts of human beings going from nongoitrous regions into localities in which goiter is endemic and there quickly acquiring the disease. One of the oldest and most striking of those given is that reported by Hancke in 1819, in which all but 70 young men of a battalion of 300 in the course of a year developed such pronounced goiter that it was found necessary to remove the regiment to a nongoitrous region, where those who were not too far advanced recovered, the enlargement of the thyroid disappearing. Hancke states that in the infected region referred to

individuals who boiled the water and freed it from the precipitate which it contained and added thereto wine and sugar very rarely developed goiter. Another striking example of the same kind is that of McClelland (1835) relative to an endemic of goiter in Deoba, India. In this locality the entire population with the exception of the Brahmins had goiter. This higher caste drew their drinking water from a widely distant spring. One or two other castes which had partial access to this source numbered a considerable percentage of goiter cases, and the lowest caste, the Domes, drew their entire water supply from a goitrous well and almost every individual had goiter. The middle caste, Ragpoots, which received partly good and partly infected water from the well were infected to the extent of two-thirds of the individuals. These examples are but one or two from many in the literature. Those who desire to multiply such reports are referred to Hirsch's *Handbuch der historisch-geographischen Pathologie* (2. Stuttgart 1883, bd. 2, p. 83), and Ewald's excellent work on *Die Erkrankungen der Schilddrüse, Myxödem und Kretinismus*, in Nothnagel's *Handbuch der speziellen Pathologie und Therapie* (2. Aufl., Wien 1909, bd. 22).

It is clear both from recorded incidence in man and from experiments both with man and animals that goiter is usually acquired through the drinking water. It has been shown that from the water sources from which man acquires goiter, dogs and rats may be made to develop it. We have shown that with water in which fish develop carcinoma of the thyroid, diffuse parenchymatous enlargement of the thyroid in both dogs and rats may be produced. From these facts inferences may be drawn that there is every reason to believe that human beings also would acquire thyroid disease from the use of such water.

POSSIBLE CARRIERS.

In a disease like carcinoma of the thyroid in the Salmonidæ, which is not transmitted directly from individual to individual but which is transmitted, if at all, from the infected to the healthy by some roundabout method, the idea of carriers for the agent which we believe to be the cause of the disease is very natural. Of the recent experimenters with goiter water, Bircher, as a result of filtration experiments, for some time advocated the view that the agent of goiter was a colloidal toxin, probably liberated by some parasite incapable of passing the Berkefeld filter. The residues scraped from such filters produced in young animals very profound nutritional changes comparable to cretinism. The filterable factor which produces the nodular adenomatous form of goiter, as well as the parenchymatous hyperplastic, will not pass through the membrane of a dialyzer, but the residue upon the dialyzer membrane proved to be particularly active. These observations have led Bircher to the belief that the agent is a colloid, but he recognizes that it may also be a filterable microorganism; or that if the organism itself does not pass the filter it is still the probable source of a filterable toxin.

Many authors have held that endemic goiter is certainly an infectious disease, Ewald being one of the strongest advocates of this theory, and McCarrison holds the same view. Schittenhelm and Weichardt (1912) consider it an infectious disease and

state that by immunizing rabbits with goiter water which was free from all bacteria or other cultivable organisms, they have gotten with the blood of such immunized rabbits a definite deviation of the complement reaction, as against the suppositious organism in the water. By means of the epiphanin reaction they believe they have demonstrated the existence of an antibody opposed to microorganismal albumin.

Kolle (1909) attempted to test the theory that intestinal parasites bore a relation to endemic goiter. McCarrison (1909) was of the opinion that the agent of goiter was in the intestinal tract, because of the prompt results obtained in his experience by the giving of a single or repeated doses of thymol. He (1911) tested this hypothesis experimentally by mixing the feces of goitrous men with sterilized soil and he fouled water with this mixture by pouring it through a specially constructed box. In one of these boxes he placed 500 earthworms on the assumption that they might be an intermediary host of the infecting agent. Water from the first box was given to six female goats and from the second with the earthworms to seven female goats. These goats were permitted to consume this highly polluted water for 64 days with the following results: First, loss of weight due doubtless to confinement in a small hut for the 64 days of the experiment; second, many of them suffered from diarrhea; third, 50 per cent of the animals showed marked enlargement of the thyroid gland, most marked on the right side. The thyroids of three goats showed no enlargement. The enlargements were of various degree. McCarrison gives the average weight of the normal thyroid of the goat of Gilgat as $\frac{1}{10000}$ of the body weight. The enlarged gland of the goats in the experiment weighed from $\frac{1}{4272}$ to $\frac{1}{7000}$ part of the body weight. In both batches receiving the fouled water the results observed were the same.

Microscopical examination of the enlarged organs by McCarrison showed "various degrees of dilatations of the vesicles and no alterations in the connective tissue stroma of the enlarged glands. The hypertrophy was due wholly to the distension of the vesicles with colloid and to the formation of new vesicles from intravesicular masses of cells." He concludes: (1) An hypertrophy of the thyroid gland of goats may be induced by infecting the water supply with feces from sufferers from goiter. It is at present impossible to state whether this hypertrophy is due to the action of the infecting agent of goiter or only to the organic impurity of the water thus contaminated. (2) Earthworms do not appear to be concerned in the spread of goiter. (3) The microscopic appearances described are the earliest changes in the formation of parenchymatous goiter.

One of the most interesting recent discoveries in relation to a parasitic thyroiditis is found in the publication of Carlos Chagas (1911). This author, cited by Schittenhelm and Weichardt, found in an insect, a Brazilian bedbug (barbeiro, *Conochinus megistus*), a flagellate which he identified as part of the developmental cycle of *Trypanosoma minasense* Chagas, which he had discovered in the silky monkey. If the infected bedbugs were allowed to bite this variety of monkey the latter received a blood infection with the organism. The bedbug is therefore the intermediary host and the incubation period after the bite is eight days. Chagas undertook to determine the original host for this organism and found in the State of Minas Geraes, especially in

children, a flagellate disease which, when the patient was transferred to Rio Janeiro, he was able to transfer to the silky monkey by means of the barbeiro. The characteristic symptoms of the disease in the children were enlargement of the thyroid, the stupefied appearance of the child, and enlargement of the lymphatic glands. He also succeeded in inoculating guinea pigs with the flagellate organism by injecting the blood of the infected children.

He divided the disease into an acute and a chronic form. The chronic form is characterized by hypertrophy of the thyroid affecting one or both of the lobes of the thyroid and frequently the isthmus. Even in young children the enlargement of the thyroid may be very marked. He says that in some regions the disease is very widespread and here infantilism and cretinism are very prevalent. All these individuals presented the characteristic enlargement of the thyroid. The histologic picture of the disease is in part an inflammatory reaction of the stroma of the thyroid with outspoken sclerosis. In such cases the alveoli are small and the lumen reduced. The colloid is usually decreased in amount and stains poorly. In the vesicles there appears to be desquamation and degenerative changes of the epithelium which fill the lumina of the alveoli. The islands of epithelium which normally lie between the vesicles appear to have been increased by proliferation, in some covering extensive areas. Large cysts filled with colloid characterize the last stages of the chronic form, with occasional calcification of the cyst wall.

In cancer of various kinds intermediary carriers have been suspected. The well-known association of cancer in Bilharzia disease with the important trematode parasite, *Distomum haematobium*, is classic. Borrel in 1906 reported having found very frequently in mouse cancer, in the immediate neighborhood of or within the tumor, occasional small nematode worms. These, he did not think, were themselves in etiologic relation to the tumors, other than as possible carriers of a specific virus. This theory was strengthened in his mind by finding in the left kidney of a rat, which died of a cancerous tumor in the right kidney, a small cyst containing a very young cysticercus, which was identified as belonging to the *Tænia crassicola* of the cat. Upon the membrane of this cyst, which was attached to the tissue of the kidney, he found a small tumor of identical structure to that of the larger tumor of the right kidney.

In the second case, furnished him by Laveran, a rat died of a tumor of the liver of the size of an orange, in the exact center of which was found a cyst with a tumor growing out from it in all directions. This cyst contained a cysticercus which was again identified as belonging to the *Tænia crassicola* of the cat. Microscopically this tumor was a large-celled sarcoma. Bipolar and multipolar karyokinetic figures were very numerous. This tumor proved to be transplantable and had produced large tumors for three or more generations. Borrel felt that the successful transplantation of this tumor strongly indicated that the cysticercus had carried with it a virus which it was possible to propagate with the cells. Finally he called attention to the possible relation of helminthia and cancer and felt that this hypothesis was in accord with the frequent tumors of the digestive tracts and the appendix. He thought that the endemic occur-

rence of cancer in animals might be explained by the distribution of some nematode or other carrier.

Regaud (1907) reported two rats in one of which he found at autopsy a general sarcomatosis of the peritoneum. At the border of the liver hung a cyst which contained a cysticercus. The neoplasm was a sarcoma with fusiform elements. Inoculation into five rats remained negative. The second, an adult male, having been found dying without known cause, was killed. In the peritoneum a tumor the size of a nut had developed in the large omentum. There were numerous miliary granulations around the tumor. At the center of it was a smooth cavity containing a tapeworm 25 centimeters long and living. Intraperitoneal inoculations made in five rats were negative. The parasites in both cases were identified as cysticerci of the *Tænia crassicola* of the cat. In common with Borrel, Regaud felt that the cysticerci in these instances were the carriers of a virus, as he had frequently found cysticerci in the liver of rats killed for histological research without accompanying neoplasms.

That a virus of cancer is no longer hypothetical has been shown by the recent demonstration by Peyton Rous in three varieties of sarcoma in chickens of a filterable virus capable of producing type-true neoplasms. This agent passes through a medium-grade Berkefeld filter. It is preserved by glycerin, has a killing point slightly higher than the cells of the chicken, is not injured by freezing, and is killed at 55° C. The agent can be preserved by drying the cells and can withstand grinding. After many months the agent can be separated from the dried cells by filtration, or, in common with them, on injection inaugurates at the point of trauma the growth of a malignant sarcoma of the type from which the virus has been taken. Rous has separated the filterable virus from a spindled-celled sarcoma (1910), an osteo-chondro-sarcoma (1912), and a spindle-celled (intracanalicular) sarcoma (1913) with peculiar arrangement of the cells. The virus of the osteo-chondro-sarcoma possesses the remarkable quality of causing the connective tissue with which it comes in contact to proliferate and specialize by forming cartilage and bone. His experiments not only show the existence in these tumors of a filterable virus but the existence for each type of a special virus. It is needless to point out that the agent of goiter is also filterable, which fact should strengthen the theory that the goiter agent is a living organism and not a soluble toxin.

Haaland, Loewenstein, von Wasielewski, and others have found helminthia in mouse cancers.

The theory of Borrel regarding nematodes has recently been experimentally proven by Fibiger (1913). Fibiger found in three rats in his laboratory large papillary growths of the stomach, in all of which were many small nematode worms. These growths he held to be fibroepithelial tumors, probably malignant, an opinion which was strengthened by microscopic examination. The epithelial proliferation was found to have broken through the muscularis mucosa, and the submucosa contained projections and islands of squamous epithelium. To determine how frequent the disease might be in Copenhagen, he examined 1,144 rats without finding any evidence of the disease. Later his attention was drawn to cockroaches as possible carriers of such nematodes, through an article by Galeb in 1878, who found nematodes in the stomachs of rats after feeding

them the cockroaches, *Periplaneta orientalis*. These he identified as *Filaria rhytiplerites* of des Longchamps. After examining 61 rats from a locality in Copenhagen which was infested with *Periplaneta americana*, he found similar worms in the stomachs of 40, of which 9 had well-developed tumors and 9 inflammatory reaction of the mucosa, which he held to be the beginning or precancerous stage of the disease. Furthermore, he reports that by feeding 57 laboratory rats with *Periplaneta americana* from the same locality he found the worms in the stomachs of 54, in 7 of which were definite tumors and 29 of which had the precancerous stage of the disease. Two of these tumors were found certainly to have metastases, probably three. The metastases did not contain the nematodes, and furthermore, Fibiger states that there is no direct relation between the intensity or amount of proliferation and the location of the worms in the gastric mucosa.

The life history of these worms is as follows: They live in the squamous epithelium of the esophagus and stomach of the rat. In rare cases they are found in the epithelium of the tongue and the mouth cavity. Here they reach the reproductive stage and eject eggs which, with the desquamated epithelium, are carried out with the excreta. In the excreta they are taken up by the cockroach *Periplaneta orientalis*, and in these insects the eggs develop into free embryos, wander into the striated musculature of the prothorax and the extremities. Here they remain for about six weeks or a longer time as trichina-like spirally coiled larvæ. If the cockroaches are consumed by the rats the larvæ are freed from their capsules and wander into the squamous epithelium of the rat's stomach, occasionally into the esophagus or the epithelium of the mouth or tongue. Here after two months the female begins to deposit eggs. The measurements of these worms in the fully developed stage are, for the male, one-half to 1 centimeter long, diameter, 0.1 to 0.16 millimeter; females, 4 to 5 centimeters long; diameter, 0.2 to 0.25 millimeter. The eggs are oval, clear, with double contour membrane, at the poles slightly thicker than at the circumference. The eggs measure 0.06 by 0.04 millimeter. They contain a rolled-up embryo with annular divisions of the cuticle. They have been identified as belonging to the genus *Spiroptera*. The male has a large bursa, with two spicules of different lengths and four preanal, as well as four postanal papillæ, on each side, these characteristics serving to distinguish them from the *Spiroptera obtusa*, as well as from the *Filaria rhytiplerites* of Galeb. It is therefore a new nematode.

In the sections of the hyperplastic thyroids in our second series of experimental dogs, we were interested to find in the capsule and in the substance of the thyroid small tubercles measuring usually 0.3 by 0.35 millimeter, of strikingly uniform appearance. At the periphery of these tubercles is a fibrous connective tissue capsule of thin and flattened cells. Within the outer layer of flattened fibrous connective tissue a more cellular structure composes the body of the tubercle. These are large fibroblasts of spindle form with oval, vesicular nuclei. They have a general arrangement, as if perpendicular to the circumference. The center of the tubercle is composed of intercellular substance with usually a zone of leucocytes, and by aid of serial sections, usually in the center of these tubercles, one encounters a cross or oblique section of a small nematode

worm. (Fig. 124.) Occasional tubercles will be encountered in which either the head (fig. 123) or tail of this worm lies near the periphery, and in some instances a fully formed tubercle has been encountered with cross sections of the worm lying without the connective-tissue capsule usually coiled in undulating fashion. (Fig. 122.) The worms appear to be of the same species. For the purpose of identification, sections of the worms have been submitted to B. H. Ransom, Chief of the Zoological Division of the Bureau of Animal Industry of the United States Department of Agriculture at Washington. We are indebted to Dr. Ransom for the following notes:

After examining the preparations I fail to identify the parasite to which you call attention with any known species. As it is quite different from a hookworm larva it is not *Ancylostoma caninum* or any other species of hookworm, a possibility which would perhaps first suggest itself, inasmuch as the larval stages of *Ancylostoma* en route to the alimentary tract are likely to be found in various tissues, though apparently they have not yet been noted in the thyroid gland. As to other possibilities, so far as I have been able to determine, no nematode has been recorded from the thyroid gland of dogs. Furthermore, the form in question does not agree in morphology with any adequately described nematode known to occur in the dog in any part of the body.

The nematodes in this case, which are sexually undeveloped, may be (1) immature stages of some species which occur in its adult stage in the dog and whose larvæ after gaining entrance to the body perform more or less extensive migrations before reaching their final location, and would thus be comparable to *Ancylostoma*, whose larvæ regularly migrate from the skin to the digestive tract, or to *Spiroptera sanguinolenta*, whose larvæ, it is stated, sometimes migrate from the digestive tract to the blood vessels and other rather remote locations where development to maturity may occur; (2) they may conceivably belong to some species like *Ollulanus tricuspis*, whose young, according to Leuckart, may either pass out of the body to become encysted in an intermediate host or penetrate into various tissues of the original host and become encysted in the manner of *Trichinella*; (3) they may be the larval stage of some species whose adult stage occurs in another host, the dog acting as a true though perhaps unusual intermediate host; or (4) they may be present in the dog as the result of an accidental infection entirely outside the normal life cycle, this case being comparable to that of the infestation of mice and other animals with the larvæ of *Spiroptera sanguinolenta* to which Seurat (1912, Compt. rend. Soc. de biol., Paris, v. 73, p. 279) has called attention. This author notes that these larvæ which are found in cockroaches, instead of developing to maturity as when fed to dogs, if fed to white mice pass through the wall of the digestive tract and become encapsuled in various organs without undergoing further development. The possibility last suggested (4) is also comparable to that of the migrations of the larvæ of *Ancylostoma duodenale*, a human parasite, in dogs. The larvæ of this species penetrate the skin of dogs and in course of time may reach the intestine, undergoing a partial development which, however, falls short of maturity.

As a rule when nematodes or other parasites are found in a given host it is to be presumed that the animal is playing the part of a true host and that there is a more or less complete adaptation between the host on one hand and the parasite on the other. The possibility, however, should not be lost sight of that larval nematodes of an unknown species found in a certain host, or of a known species found in an unusual host, may represent individuals which have gone astray so far as the possibility of completing their normal life cycle is concerned. It is apparently true that nematodes which thus go astray usually die before there is any development or any invasion of the tissues of the animal. That is, nematodes entering the digestive tract of an animal which is unsuitable as a host as a rule quickly succumb without doing any damage. This is, however, not the case with all species, for example, *Spiroptera sanguinolenta* in mice, as noted above. Similarly in the case of nematodes whose normal mode of entrance is through the skin it is to be presumed that they will not even enter the skin of an unsuitable host, but such occurrences may not be very unusual. The case of *Ancylostoma duodenale* already mentioned, and that of *Strongyloides stercoralis*, another human parasite, which behaves much

as *A. duodenale* with reference to dogs, are sufficient to indicate that stray parasites may enter the body through the skin as well as through the mouth, and perform extensive migrations through the tissues and even undergo a partial development before they die. The possibilities as to the amount of damage such stray parasites may do are interesting. They may, for instance, have more injurious effects on the unusual host than on the animal to which they are specifically adapted, much as in the case of various parasitic protozoa which do not injure certain animals considered to be their usual hosts, but are very injurious to others considered unusual hosts. The two cases are of course not strictly comparable as there would be no multiplication, at least no repeated multiplication, in the case of the nematode like that in the case of the protozoan. The introduction of microorganisms by nematode larvæ is another possible source of damage, and this applies not only in the case of stray parasites but in the case of those entering their proper host animals. Many parasitic nematodes have plenty of opportunity during the early stages of their free living existence while they are actively feeding upon the organic materials in the medium, commonly fecal matter which surrounds them, to pick up injurious microorganisms, and these it is quite conceivable may be carried with them on their later migrations and finally deposited where damage will result. Looss (1911, Rec. Egypt. Govt. School Med., Cairo, v. 4, p. 557), for example, suggests that *Ancylostoma* larvæ which have developed in feces might retain some bacteria in their intestine and evacuate these as soon as they arrive in the body of their host, and that this if it occurred might have something to do with the skin lesions which accompany *Ancylostoma* infections.

Returning to the nematodes in the thyroid of the dog, it has not seemed advisable to venture an opinion as to the genus or even the family to which the parasites may belong. In order that they may not be left nameless I have designated them as *Agamonematodum gaylordi*, thus placing them in a collective group, which is used for convenience of reference to include various immature nematodes, whose sexually mature stage is undetermined. The following brief description is based on an individual the anterior portion of which is present in the sections on a slide labeled "Dog 17. K. 1-22-12.20, Nem. 2". (Fig. 123.)

AGAMONEMATODUM GAYLORDI.

Length uncertain, but apparently less than 1 millimeter; maximum width 35μ . Head apparently with 3 lips, each supplied with a small papilla. Diameter of head at level of papillæ 20μ , increasing to 24μ at a distance of 20μ from the anterior end, then rather suddenly constricted to 20μ , after which the diameter of the body gradually increases, reaching 32μ at the level of the nerve ring, which is located about 100μ from the anterior end of the body. Mouth very small, communicating directly, without intervening larynx or mouth capsule, with the esophagus. Esophagus near its anterior end measures about 16μ in diameter, is then constricted slightly, corresponding with the constriction of the body, and gradually increases again in diameter, attaining a size of about 18μ in the neighborhood of the nerve ring. Length of esophagus uncertain, but exceeds 160μ . The anterior end of the body is supplied with narrow lateral cuticular wings, which extend posteriorly an unknown distance beyond the esophageal region.

Host.—Dog (*Canis familiaris*).

Location.—Thyroid gland in small tubercles.

Locality.—Craig Brook, Me.

The nematodes were not found in the two dogs examined in 1910, one of which had marked thyroid hyperplasia and the other a nearly normal gland, but serial sections were not available. In all (3) of the puppies which had marked hyperplasia and were given drinking water in which were suspended scrapings (dog 16, dog 17, and dog 22) nematodes are present. In the white mongrel adult dog with the highest degree of diffuse parenchymatous hyperplasia and degeneration (dog 18) they are also present. In the control for this dog, the mother of the puppies, which received boiled water (dog 19), they are not present. In the control puppy no. 21, which received boiled water, they

are not present. In the second control puppy, no. 20, they are present. It is this control, no. 20, which is described as having slight evidence of hyperplasia, but as this dog received before the beginning of the final experiment, as did also the other controls, water from pond 10, it is possible that it acquired the worms at that time. The mother dog, no. 19, and the other control puppy, no. 22, also received pond 10 water and showed no evidence of hyperplasia or nematodes.

There is apparently no direct connection between the hyperplasia of the thyroid and the nematodes. As previously described, the hyperplasia of the thyroid in these experimental animals is diffuse. If the nematodes have any direct relation to the experimental hyperplasia of the thyroid thus produced, it is only as a carrier of the virus of the disease in the manner which Borrel has suggested for tumors in mammals. That hyperplasia can result without nematodes or other possible carriers is shown by the fact that we have not found anything of the sort in the hyperplasia of the thyroid in the rats, induced with water and scrapings from Craig Brook. Bircher or the other authors who have produced experimental goiter in animals have not noted the presence of nematodes. Nematodes in the region of the thyroid in fish are certainly not necessary to the development of the disease in fish. We have in one or two instances found similar tubercles usually lying in the subcutaneous tissue below the floor of the mouth in which coiled-up nematode remains have been found. A portion of the cuticle of such a nematode was sufficiently preserved so that its structure could be clearly made out. (Fig. 126.) There is evidence in the dog thyroids that some of the nematodes perish. The finding of disintegrating tubercles is subject to this interpretation. (Fig. 125.) It is therefore possible that in the very early stages of the transmission of the disease it will be found that such nematodes act as occasional carriers in this affection and that later they disappear. A careful study of the intestinal contents of the fish and the scrapings from the fish troughs will be included in the next stage of this investigation.

SUMMARY.

I. The present investigation of thyroid carcinoma among fish was begun by the Director of the Gratwick Laboratory in furtherance of the inquiry of that institution into the nature of cancer in man. Having brought it to the attention of the United States Bureau of Fisheries through the President of the United States, an investigation of wider scope resulted, based upon its interest and importance to fish culture and to cancer research in general, and uniting the Federal and State resources as represented by the Bureau and the Gratwick Laboratory.

Bonnet in 1883 described a gill disease in trout which is undoubtedly identical with the subject of this inquiry, and is thus the first published reference to it, though the nature of the disease was not at that time recognized. Scott in 1891 first identified the disease as carcinoma, without recognizing its relation to the thyroid gland. Its origin in the thyroid was first asserted by Plehn in 1902, who diagnosed it as adeno-carcinoma. Pick in 1905 published the first extended study of the structure of the growths and insisted on their carcinomatous nature. Gillruth in 1902 described it briefly as an

epithelioma affecting the branchial arches and showed that it was widely distributed among the hatcheries of New Zealand.

Gaylord began the study of the disease in 1908 and reported evidence pointing to an infectious factor in its causation. Marine and Lenhart, as the result of studies in 1909 and subsequently, hold that the disease is endemic goiter and have failed to find any specimens which they recognize as cancer.

The disease is widely distributed throughout the United States and probably occurs more or less everywhere that artificial propagation of salmonoids is carried beyond the early stages.

II. The normal thyroid follicles in salmonoids resemble those of the mammalian thyroid, but the gland is not encapsulated and not so definitely confined within given limits. In wild brook trout the largest masses of thyroid follicles are faintly macroscopic, and all the thyroid tissue is located in the neighborhood of and chiefly dorsal to the ventral aorta between the first and third gill arches, and does not extend laterally along the arches. The distribution is somewhat more restricted than that indicated by Gudernatsch. Anomalous deposits frequently occur beneath the epithelium of the jugular pit, but are rare elsewhere. The thyroid follicles of wild trout are regular in shape, usually spherical or slightly elongate and in the typical or simplest condition its epithelium is flattened or never higher than cuboidal.

III. Simple hyperplasia of the thyroid is met with in trout living under wild conditions. The follicles are increased in number, are more irregular in shape, the colloid is diminished, and the epithelium is in large part columnar. Such a hyperplasia exists also in domesticated trout and is not to be distinguished from the earliest stages of carcinoma of the thyroid. The immune Scotch sea trout as yearlings occasionally exhibit this simple hyperplasia, and a few adults are found with colloid goiter. Spontaneous recovery from thyroid carcinoma in fish does not result in this picture of colloid goiter.

IV. The first macroscopic evidence of the disease is usually found in an area of hyperemia on the floor of the mouth (red floor). The first evidence of visible tumors may be found at the branchial junction. Tumors may protrude in various directions, at the branchial junction, in the floor of the mouth, or to either side of the gill region. Independent tumors develop in the jugular pit, a region which frequently contains deposits of normal thyroid tissue. The first microscopic evidence of the disease is found to occur in individual follicles, usually those nearest a large vessel. A small group of altered follicles surrounded by normal follicles is frequently found in the early stages. The epithelium is high cubical or columnar, the protoplasm and nuclei stain deeply. Colloid is diminished or absent, the vessels of the stroma hyperemic. Budding of the wall of the follicle next occurs, forming isolated new follicles of irregular type, and papillary projections into the follicles. As the gland is not encapsulated, newly formed tissue grows between the muscle planes and fills in the areolar spaces. At this stage karyokinetic figures are common, the epithelium is high columnar, and frequently there are several layers of epithelium in a single follicle. Proliferation may now have

reached a sufficient amount to produce the red-floor stage. Bone, cartilage, and muscle are invaded. The growth no longer seeks the paths of least resistance.

In the visible tumor stage there is a remarkable variation in the character of the proliferation. All the various types occur in one tumor. They may be divided into alveolar, tubular, and solid, and combined with papillary and cystic types. Frequently small adenomatous structures of malignant appearance are found invading and infiltrating the surrounding thyroid structure of less malignant appearance. Occasionally islands of normal thyroid tissue have been found in the bone spaces or cavities of the bone where the entire surrounding structure was replaced by thyroid carcinoma. True infiltration of bone, cartilage, vessel wall, muscle, and skin has been demonstrated. Occasionally tumors are met with which present the appearance of so-called sarco-carcinoma of the thyroid in mammals; a background of spindle cells resembling sarcoma with occasional alveoli.

Growths upon the apex of the lower jaw are either implantations or metastases. A marked similarity of the primary tumor in the thyroid region with the growth upon the tip of the jaw in one case studied indicates that this is probably metastasis formation at the site of an injury. An undoubted case of metastasis formation is found in a tumor growing in the intestinal wall at the lower end of the intestinal tract, which infiltrated the muscularis mucosa of the intestinal wall, of characteristic thyroid carcinoma structure, large irregular follicles lined with columnar epithelium, occasionally containing colloid. Portions of the tumor present an appearance closely approximating the least malignant appearing primary tumors. The character of this growth and the region in which it occurred shows conclusively that it is a metastasis.

A comparison of the various types of thyroid carcinoma of the Salmonidæ shows that they approximate in type three of the groups made by Langhans for carcinoma of the thyroid in mammals, viz, proliferating struma, carcinomatous struma, and malignant papilloma.

V. Three examples of the disease have been found in wild fish in the United States. One occurred in a brook trout which may have been planted from a hatchery, one in a landlocked salmon, and one in a whitefish. None of the species of whitefishes is fed or reared artificially.

VI. The disease has been observed in 16 species of salmonoids, or in hybrids made among these.

The geological formation at the sources of the water supplies in which the disease occurs has apparently nothing to do with its origin, nor has the dissolved content of the water.

The disease is usually endemic and occasionally epidemic. It occurs in ponds and troughs, of whatever construction, in which fish are held, reared, and fed the ordinary proteid foods of fish culture, viz, raw liver, heart, lungs, and other meats. It shows a tendency to increase from above downward in the course of a given water flow. Hybrids of the Pacific salmon are especially susceptible and show a high incidence. When endemic, the course of the disease is slow and chronic, with a low death rate made indeterminate by complication with intercurrent or terminal infection and other causes of death. The incidence of tumors varies greatly and increases with the age of

the fish. Macroscopically visible growths have not been seen in fish under about five months of age. Anemia and cachexia, sometimes extreme in degree, are a frequent but not constant accompaniment of the disease. Immunity is strikingly exhibited not only among species, as the Scotch sea trout, but with given lots of a susceptible species. Recovery or regression occurs when affected fish are removed from domestication to wild conditions and also in fish in ponds in which the disease was acquired.

VII. Feeding of fish tumors, or of human cancer, to brook trout has not during a period of several months produced the slightest evidence of the disease attributable to this feeding. The intimate association of susceptible trout with trout tumor material in standing water, or with tumor fish in circulating unchanged water, has brought only negative results. The fish tumor has not yet been successfully transplanted, but implants have grown slightly and were alive at the end of three months. The tumor extract is highly toxic to trout when injected into the thyroid region or subcutaneously.

Wild brook trout brought from the wilderness and confined in cement tanks and fed raw heart or raw liver have developed microscopic evidence of the disease by the end of the first year, and visible carcinoma between the first and second year. The feeding of cooked liver retarded the process. Spontaneous regression occurred in a high percentage of the meat-fed fish by the end of the second year. Similar trout fed upon marine fish, vegetable food, or a combination of mussels and live maggots retained their normal thyroids.

VIII. Either of the elements iodine, mercury, or arsenic dissolved as salts in the water in which the fish are living interrupts the progress of the disease and restores the thyroid epithelium to a condition approximating the normal. Recognizable effects are produced within a few days. Visible tumors are markedly affected and may be much reduced in size. Iodine and mercury are effective even when diluted by many millions of parts of water. Iodine is effective when introduced into the digestive tract as well as through the medium of the water. Negative results were obtained with thymol by both these methods of administration.

IX. The administration to dogs of mud and water from fish ponds in which thyroid carcinoma was endemic gave suggestive evidence that the water and mud contained an agent capable of producing marked changes in the thyroid. Scrapings from the inside of old wooden fish troughs in which thyroid carcinoma was constantly produced gave positive results. Four dogs were given for six months water to drink in which these scrapings were immersed. All developed marked thyroid hyperplasia and three of them enlarged thyroids. The thyroids of the three control animals remained of normal size. Two of them were normal in structure while one showed slight evidence of hyperplasia, probably referable to a previous experiment.

Rats given for six months mud and water which had been taken from ponds in which thyroid carcinoma was prevalent and transported several hundred miles gave negative results. Rats given for four months water from the fish trough scrapings, also transported as above, produced results similar to those obtained with the dogs but less marked in degree.

X. In the hyperplastic thyroids of three puppies and one adult dog which were given pond mud and water, or water from fish-trough scrapings, minute nematode worms were found immediately beneath the capsule or in the substance of the thyroid. The worms were surrounded by connective tissue tubercles. In two instances only remains of small nematode worms were found in the thyroid region of brook trout with carcinoma of the thyroid undergoing regression. If these worms have any etiological significance it must be merely as carriers of a causative agent.

CONCLUSIONS.

1. The disease known as gill disease, thyroid tumor, endemic goiter, or carcinoma of the thyroid in the Salmonidæ, is a malignant neoplasm.

2. The disease occurs in fish living under conditions of freedom in populated areas.

3. When introduced into fish-breeding establishments it becomes endemic with occasional epidemic outbreaks.

4. Normal fish taken from the wilderness may be made to acquire the disease when placed in fish-breeding establishments where the disease is endemic.

5. The feeding of uncooked animal proteid favors and the feeding of cooked animal proteid retards the disease as compared with the uncooked. Feeding alone is not an efficient cause. It must be combined with an agent transmitted probably through the water or food, or both.

6. By scraping the inner surface of water-soaked wooden troughs in which the disease is endemic, an agent may be secured which from its action upon the mammalian thyroid when administered through drinking water is no doubt the cause of the disease in the fish confined in these troughs.

7. The agent is destroyed by boiling.

8. Fish in all stages of the disease are favorably affected in the direction of cure by the addition to the water supply in suitable concentration of mercury, arsenic, or iodine.

9. The effect of mercury, arsenic, and iodine in carcinoma of the thyroid in fish and the subsequent positive experiments with metals in mammalian cancer are probably the expression of a therapeutic relation of these elements to carcinoma.

10. Certain species of the Salmonidæ have an almost complete natural resistance to the disease.

11. Certain lots of fish of susceptible species show a high degree of immunity to the disease.

12. Spontaneous recovery occurs in a considerable percentage of individuals.

13. Removal from ponds in which the disease is endemic to natural conditions, or a change to more natural food, increases the percentage of spontaneous recoveries.

14. Spontaneous recovery appears to confer a degree of immunity against recurrence.

15. The percentage of spontaneous recoveries in the early stages of the disease appears to be higher than in the later stages of the disease.

16. The incidence of the disease increases with the age of the fish, at least up to five years.

17. Thyroid enlargement and changes presenting at the end of five months a picture of diffuse parenchymatous goiter were induced in mammals by giving them water to drink in which had been suspended scrapings from troughs in which the disease is endemic. Control animals which receive the same water boiled failed to develop thyroid changes. That these enlargements and changes are the first stages in mammals of the same disease which occurs in the fish inhabiting the troughs from which the scrapings were obtained, is an inference which we believe further experiments will justify.

18. The disease is endemic in a very high percentage of all trout hatcheries in the United States.

19. The occurrence of the disease in wild fish, its introduction into fish-cultural stations, its localization in certain troughs or water supplies, the method of its spread, its transmission to mammals, the efficacy of three well-known inorganic germicides in the treatment of the disease, the destruction of the agent by boiling, the phenomena of spontaneous recovery and immunity, strongly indicate that the agent causing the disease is a living organism.

20. No evidence has yet been produced to indicate the direct transmission of the disease from individual to individual.

21. In many of its phases the disease is identical with endemic goiter. As there is no line of demarcation between what is called endemic goiter and what we believe we have clearly shown is cancer of the thyroid, we hold that endemic goiter and carcinoma of the thyroid in the Salmonidæ are the same disease.

ZUSAMMENFASSUNG.

I. Die gegenwärtige Untersuchung des Schilddrüsen-Krebses unter den Fischen wurde von dem Leiter des Gratwick-Laboratoriums eingeleitet zwecks Foerderung der Untersuchungen dieses Institutes betreffs der Natur des Krebses beim Menschen. Nachdem durch die Vermittlung des Praesidenten der Vereinigten Staaten das Interesse unserer Central-Bureaus fuer Fisch-Zucht gewonnen war, nahm die Untersuchung eine beträchtliche Ausdehnung gestützt auf die Wichtigkeit derselben fuer die Fisch-Zucht und für die Krebs-Forschung im Allgemeinen. So wurden fuer den Zweck die Huelfskraefte des Landes (Centralbureau fuer Fisch-Zucht) und des Einzel-Staates (Gratwick Laboratorium) vereinigt.

Bonnet beschrieb im Jahre 1883 eine Kiemen-Erkrankung der Forelle, welche zweifellos mit dem Gegenstand unserer Untersuchungen identisch ist, und dies ist die erste diesbezügliche Mitteilung, wenn auch die Natur der Erkrankung damals nicht erkannt worden war. Scott erklarte die Erkrankung im Jahre 1891 als erster fuer Krebs, ohne ihre Beziehung zur Schilddruese zu erkennen. Ihr Entstehen in der Schilddruese wurde zuerst von Plehn im Jahre 1902 behauptet, welcher die Krankheit als ein Adeno-Carcinom diagnostizierte. Pick veroeffentlichte als erster im Jahre 1905 eine eingehende Erforschung der Struktur dieser Neubildungen und erklarte sie absolut fuer Krebs-Tumoren. Gilruth beschrieb dieselben in 1902 als Epitheliom der Kiemenboegen und wies nach, das sie in den Fisch-Brutanstalten Neu-Seelands sehr verbreitet waren.

Gaylord began das Studium der Erkrankung im Jahre 1908 und berichtete Tatsachen, welche auf eine Infektion als Ursache hinwiesen. Marine und Lenhart behaupteten im Jahre 1909 und spaeter als das Resultat ihrer Untersuchungen, dass die Krankheit ein endemischer Kropf waere. Sie konnten in ihren Praeparaten keinen Krebs feststellen.

Die Erkrankung ist in den Vereinigten Staaten weit verbreitet und kommt wahrscheinlich mehr oder weniger ueberall vor, wo die Züchtung von Salmoniden ueber das fruehste Stadium hinaus fortgefuehrt wird.

II. Die Follikel der normalen Schilddruese in der Lachs-Gruppe aehneln denen der Saeugetier-Schilddruese, aber die Druese ist nicht eingekapselt und nicht so scharf abgegrenzt. Bei der wilden Bach-Forelle sind die groessten Häufchen der Follikel makroskopisch eben wahrnehmbar, und das gesammte Schilddruesengewebe ist in der Naehة der Ventral-Aorte hauptsaechlich dorsalwaerts derselben gelagert zwischen dem ersten und dritten Kiemenbogen. Sie dehnen sich nicht lateralwaerts laengs den Kiemenboegen aus. Die Lage is mehr beschraenkt als nach der Angabe von Guder-natsch. Haeufig sieht man anomale Follikel-Anhaeufungen unter dem Epithel der Jugular-Vertiefung, aber kaum irgend wo anders. Die Schilddruesen-Follikel der wilden Forelle sind von regelmaessiger Gestalt, gewoehnlich kugelig oder laenglichrund, in der typischen oder einfachsten Form haben sie ein flaches, jedenfalls nie hoeher als wuefelfoermiges Epithel.

III. Einfache Hyperplasie der Schilddruese findet man bei der wilden Forelle. Die Follikel sind zahlreicher, unregelmässiger in Form, das Colloid ist vermindert und das Epithel ist zum grossen Teil säulenfoermig. Solch eine Hyperplasie kommt auch beider zahmen Forelle vor, und dieselbe lässt sich nicht von dem frühesten Stadium des Schilddruesen-Krebses unterscheiden. Die immune See-Forelle (*Salmo trutta*) zeigt gelegentlich im ersten Jahr diese einfache Hyperplasie und im ausgewachsenen Zustand findet man einzelne mit colloidem Kropf. Spontanheilung des Schilddrüsen-Krebses beim Fisch zeigt nicht dieses Bild des colloidem Kropfes.

IV. Das erste makroskopische Anzeichen der Erkrankungen ist gewöhnlich ein hyperämischer Fleck in dem Boden der Mundhöhle (red floor). Das erste Zeichen einer sichtbaren Neubildung findet man an der Kiemenbogen-Vereinigung. Deutliche Tumoren können entweder hier oder auf dem Boden der Mundhöhle oder zu beiden Seiten der Kiemenbögen hervorwachsen. Selbständige Tumoren entwickeln sich in der Jugular-Vertiefung, woselbst nicht selten Anhäufungen von normalem Schilddrüsen-Gewebe zu finden sind. Die ersten mikroskopischen Anzeichen der Erkrankung findet man in vereinzeltten Follikeln, gewoehnlich denen welche einem grossen Blutgefäss benachbart sind. Eine kleine Gruppe von veränderten Follikeln sieht man oft im Frühstadium umgeben von normalem Gewebe. Das Epithel ist wuefel- oder säulenfoermig, das Protoplasma und die Kerne im gefärbten Präparat sind stark gefärbt. Colloid ist vermindert oder nicht vorhanden, die Gefässe des Stromas sind hyperämisch. Demnächst stellt sich Wucherung der Follikelwand ein, es bilden sich neue Follikel von unregelmässiger Gestalt und papillenartige Auswüchse in die Follikeln. Da die Drüse keine Kapsel hat, wächst das neugeformte Gewebe in die Muskelbündel hinein und füllt die Areolar-Räume.

In diesem Stadium sind karyokinetische Bilder sehr gewöhnlich, das Epithel ist hochsäulenförmig, häufig findet man mehrere Epithel-Lagen in einem einzelnen Follikel. Die Wucherung kann jetzt so weit fortgeschritten sein, dass sie das "rote Boden" Stadium erreicht. Die Neubildung verfolgt nun nichtmehr den Weg des geringsten Widerstandes. In diesem Stadium des deutlich sichtbaren Tumors zeigt derselbe eine auffallende Character-Verschiedenheit im Wachstum. Sämmtliche Typen können in einem Tumor vorkommen. Man kann alveolare, tubulare und solide Formen unterscheiden, welche im Verein mit papillären und cystischen Typen auftreten können. Häufig findet man kleine adenomatöse Gewebshäufchen von bösartigem Aussehen, welche in das umgebende, weniger bösartig aussehende Schilddrüsengewebe hineinwachsen und dasselbe durchdringen. Manchmal fanden sich Inseln von normalem Schilddrüsengewebe in den Knochenräumen oder in den Knochenhöhlen, wo das gesammte umgebende Gewebe durch Schilddrüsen-Krebs ersetzt war. Es liess sich wirkliche Infiltration des Knochens, des Knorpels, der Gefäss-Wandung, des Muskels und der Haut nachweisen. Manchmal stösst man auf Tumoren, welche das Bild des sogenannten Sarco-Carcinom der Säugetier-Schilddrüse geben; ein Hintergrund von Spindel-Zellen wie beim Sarkom mit einer Alveole hier und da. Tumoren an der Spitze des Unterkiefers sind entweder Implantationen oder Metastasen. Eine deutliche Ähnlichkeit des primären Tumors in der Schilddrüsen-Gegend mit der Wucherung an der Spitze des Kiefers, welche wir in einem Falle untersuchten, zeigte dass letztere wahrscheinlich eine Metastase an einer verletzten Stelle war. Einen unzweifelhaften Fall von Metastasis fanden wir in einer Neubildung in der Darm-Wandung am untern Ende des End-Darms. Dasselbe wuchs in die Muscularis mucosa des Darms, zeigte den typischen Schilddrüsen-Krebs-Bau, grosse unregelmässige Follikel gesäumt mit säulenartigem Epithel, hier und da etwas Colloid. Teile der Geschwulst sehen aus wie die am wenigsten bösartig aussehenden primären Tumoren. Der Character dieser Neubildung und die Localität beweisen deutlich dass es eine Metastase ist. Eine Vergleichung der verschiedenen Formen des Schilddrüsenkrebses in den Salmoniden zeigt, dass sie im Grossen und Ganzen den drei Gruppen entsprechen, welche Langhans fuer den Schilddrüsenkrebs bei Säugetieren aufstellt, nämlich: Wuchernder Kropf, krebsartiger Kropf und bösartiges Papillom.

V. Drei Fälle der Erkrankung haben wir in den Vereinigten Staaten beim Fisch im Wildzustand gefunden, einen bei einer Bach-Forelle, welche vielleicht aus einer Fisch-Züchtereı verpflanzt worden war. Die zwei andere betraf einen "Weissfisch" (*Coregonus*) und ein Lachs (*Salmo sebago*). Bei dem *Coregonus* findet weder künstliche Fütterung noch Züchtung statt.

VI. Die Erkrankung wurde in 16 Arten der Familie "Lachs" beobachtet oder in deren Kreuzungsformen. Die geologische Formation des Bodens in der Umgebung der Gewässer und ihrer Quellen, in denen die Krankheit an Fischen beobachtet worden ist, hat *wahrscheinlich nichts* mit ihrem Ursprung zu thun, ebenso wenig die im Wasser gelösten Bestandteile. Die Erkrankung ist gewöhnlich endemisch, zuweilen epidemisch. Sie kommt vor in Teichen und Wasserbehältern, was immer auch die Construction sein mag, in welchen Fische gehalten, gezüchtet und mit der gebräuchlichen Proteinhaltigen Nahrung gefüttert werden: Rother Leber, Herz, Lunge und anderen animalen Bestandteilen. Beim Verfolgen eines Flussgebiets stromabwärts sieht man

eine Zunahme in der Affektion. Kreuzungen mit dem Lachs des Stillen Oceans sind besonders empfänglich und zeigen eine hohe Krankheits-Ziffer. Die endemische Form verläuft langsam, chronisch mit einer niedrigen Sterberate, welche selbst sicherer festzustellen ist wegen der Complication mit intercurrenten Affektionen und der schliesslichen Infektion. Das Vorkommen des Tumors schwankt sehr und nimmt mit dem Alter des Fisches zu. Makroskopisch sichtbare Neubildungen waren erst nach dem fünften Lebensmonat des Fisches bemerkbar. Anämie und Cachexie, zuweilen sehr hochgradig, waren eine häufige aber nicht constante Begleit-Erscheinung. Immunität zeigt sich in auffallender Weise nicht nur bei einzelnen Arten wie bei der See-Forelle, sondern auch bei Arten welche für die Erkrankung empfänglich sind. Heilung oder Rückbildung kommt vor, wenn die erkrankten Individuen in Verhältnisse absoluten Naturzustandes übergeführt werden und auch wenn Fische in Teichen weiter gehalten werden, in welchen sie erkrankten.

VII. Füttern von Bachforellen mit Fisch-Tumoren oder mit Krebs vom Menschen während einer Periode von mehreren Monaten gab nicht den geringsten Beweis, dass eine Erkrankung solchem Füttern zuzuschreiben sei. Innige Berührungen von empfänglichen Forellen mit Forellen-Tumor-Material in stagnierendem Wasser oder mit tumor-behafteten Fischen in circulierendem unverändertem Wasser brachte uns nur negative Resultate. Der Fischtumor hat sich noch nicht mit Erfolg transplantieren lassen, aber Implantationen gelangen bis zu einem gewissen Grade, und dieselben waren nach Verlauf von 3 Monaten lebensfähig. Der Tumor-Extract ist hochgradig giftig für die Forelle, wenn derselbe in die Schilddrüse oder subcutan injiziert wird. Wilde Forellen wurden aus ihrer natürlichen Umgebung in Cement-Behälter gebracht und mit ungekochter Leber and Herz gefüttert. Dieselben zeigten die mikroskopisch nachweisbare Erkrankung am Ende des ersten Jahres und sichtbaren Krebs zwischen dem ersten und zweiten Jahr. Fütterung mit gekochter Leber verzögerte den Prozess. Spontane Rückbildung war in einem grossen Prozentsatz der fleischgefütterten Fische am Ende des zweiten Jahres nachweisbar. Forellen derselben Art mit Salzwasser-Fisch, Vegetabilien oder einer Mischung von Muscheln und lebenden Würmern genährt behielten ihre normale Schilddrüse.

VIII. Jod, Quecksilber und Arsen in ihren Salzverbindungen im Wasser gelöst, in welchem die Fische leben, unterbrechen das Fortschreiten der Erkrankung und stellen beinahe den Normal-Zustand des Schilddrüsen-Epithels wieder her. Ein deutlicher Einfluss ist schon nach wenigen Tagen bemerkbar. Sichtbare Tumoren werden wahrnehmlich beeinflusst und können beträchtlich schrumpfen. Jod und Quecksilber sind schon im millionenfachen Verdünnung wirksam. Jod ist wirksam, wenn in den Verdauungstractus gebracht und durch die Vermittlung des Wassers. Nach beiden Richtungen hin waren Versuche mit Thymol ohne Einfluss.

IX. Schlamm und Wasser von Fischteichen, in welchen Schilddrüsenkrebs endemisch war, wurde an Hunde verfüttert. Es zeigte sich, dass das Wasser ein Agens enthielt, welches imstande war, deutliche Veränderungen in der Schilddrüse zu verursachen. Material, welches von der Innenseite alter Fischbehälter abgekratzt worden war, in denen beständig Schilddrüsenkrebs produziert worden war, gab positive Resultate

Vier Hunde wurden 6 Monate lang mit Wasser getränkt, dem dieses Material beigesetzt war. Sie zeigten sämtlich ausgesprochene Hyperplasie der Schilddrüse, und drei hatten vergrößerte Schilddrüsen. Die Schilddrüsen der 3 Control-Tiere blieben normal in Grösse. Zwei davon waren normal in Bau, während eine leichte Hyperplasie zeigte, wahrscheinlich aus Gründen eines früheren Experiments. Ratten wurden 6 Monate lang mit Schlamm und Wasser aus Teichen gefüttert, in denen Schilddrüsenkrebs vorherrschend war. Dies Wasser musste mehrere hundert Meilen transportiert werden. Das Resultat war negativ. Das oben erwähnte abgekratzte Fischbehälter material wurde 4 Monate lang in Wasser an Ratten verfüttert. Das Wasser wurde ebenfalls einige hundert Meilen transportiert. Das Resultat war ähnlich wie bei den Hunden, nur nicht so ausgesprochen.

X. In den hyperplastischen Schilddrüsen von drei jungen und einem ausgewachsenen Hund, welche mit Wasser und Schlamm aus Fischteichen und Kratzmaterial aus Fischtrögen getränkt wurden, fanden wir kleinste Nematoden unmittelbar unter der Kapsel oder in der Substanz der Schilddrüse. Die Würmer waren von Anhäufungen von Bindegewebe eingeschlossen. In zwei Fällen wurden nur Überreste von kleinen Nematoden in der Schilddrüsengegend bei Bachforellen gefunden mit einem Schilddrüsenkrebs, der sich in der Rückbildung befand. Wenn diese Nematoden eine aetiological Bedeutung haben, so kann es nur die sein, dass sie Träger eines ursächlichen Agens sind.

SCHLUSSFOLGERUNGEN.

1. Die Krankheit, welche unter dem Namen Kiemen-Krankheit, Schilddrüsentumor, endemischer Kropf oder Krebs der Schilddrüse bei der Lachs-Familie bekannt ist, ist eine bösartige Neubildung.
2. Die Krankheit findet sich bei Fischen, die unter natürlichen Bedingungen in bewohnten Gebieten leben.
3. In Fisch-Züchtereien eingeführt wird sie endemisch und bricht zuweilen in Epidemien aus.
4. Normale Fische der Wildnis entnommen können an der Affektion erkranken, wenn sie in Fisch-Anstalten gebracht werden, in welchen dieselbe endemisch ist.
5. Die Fütterung mit ungekochtem Proteid Material vom Tier begünstigt, die mit gekochtem verzögert den Ausbruch der Krankheit. Fütterung allein ist nicht eine wirk-same Ursache. Es muss dazu kommen ein anderes Agens, das wahrscheinlich durch Wasser oder durch Nahrung oder durch beides übermittelt wird.
6. Durch Ausschaben der Innenfläche hölzerner wasserdurchtränkter Fisch-Bottiche, in welchen die Krankheit endemisch ist, erhält man ein Agens, welches nach der Wirkung auf die Säugetier-Schilddrüse durch Vermittlung von Trinkwasser zu urteilen ohne Zweifel die Ursache der Erkrankung der Fische ist, welche in diesen Behältern gehalten werden.
7. Durch Kochen wird dasselbe zerstört.
8. In allen Stadien der Erkrankung werden Fische günstig beeinflusst, wenn man dem Wasser in gewisser Verdünnung Quecksilber, Arsen oder Jod zusetzt.

9. Die Wirkung des Quecksilbers, Arsens und Jods auf Schilddrüsenkrebs beim Fisch und die daraufhin vorgenommenen erfolgreichen Versuche mit Metallen an Säugetieren sind wahrscheinlich der Ausdruck einer Heilwirkung dieser Elemente beim Krebs.

10. Gewisse Arten der Salmoniden haben beinahe eine völlige natürliche Widerstandsfähigkeit gegen die Erkrankung.

11. Manche Fische von empfänglichen Arten zeigen einen hohen Grad von Immunität gegen die Krankheit.

12. Spontanheilung kommt in einer beträchtlichen Anzahl von Individuen vor.

13. Übertragung aus Teichen mit endemischer Erkrankung in natürliche Umgebung oder Übergang zu mehr natürlicher Nahrung vermehrt den Prozentsatz der Spontanheilungen.

14. Spontan-Heilung scheint einen gewissen Grad von Schutz gegen Rückfall zu verleihen.

15. Der Prozentsatz der Spontan-Heilungen in den Frühstadien der Krankheit scheint höher zu sein als in den späteren Stadien.

16. Das Vorkommen der Krankheit nimmt mit dem Alter des Fisches zu wenigstens bis zum 5ten Jahr.

17. Schilddrüsen-Vergrößerung und Veränderungen, welche nach Verlauf von 5 Monaten das Bild eines diffusen parenchymatösen Strumas darboten, wurden bei Säugetieren erzeugt, wenn man ihnen Wasser zu trinken gab mit ausgeschabtem Material von Fischbottichen, in welchen die Krankheit endemisch war. Controll-Tiere, welche dasselbe Wasser gekocht erhielten, zeigten keinerlei Veränderungen an der Schilddrüse. Dass diese Vergrößerungen und Veränderungen an Säugetier-Schilddrüsen die ersten Stadien derselben Erkrankung sind, welche bei Fischen vorkommen, welche die obenerwähnten Bottiche bewohnt haben, ist ein Schluss, welchen nach unserer Überzeugung weitere Versuche rechtfertigen werden.

18. Die Erkrankung ist zu einem hohen Prozentsatz in allen Forellen-Züchtereien der Vereinigten Staaten endemisch.

19. Das Vorkommen der Krankheit beim wilden Fisch, ihre Einführung in Fisch-Züchtereien, ihre Localisation in gewissen Bottichen oder Wasserläufen, die Methode ihrer Verbreitung, ihre Übertragung auf Säugetiere, die Wirksamkeit von 3 wohlbekannten Gemiciden inorganischer Natur bei der Behandlung der Krankheit, die Zerstörung des Agens durch Kochen, die Erscheinungen der Spontan-Heilung und der Immunität, weisen dringend darauf hin, dass das ursächliche Moment der Krankheit ein lebender Organismus ist.

20. Es ist bisher kein Nachweis geliefert, dass die Krankheit von einem Individuum auf das andere übertragen wird.

21. In einer Reihe von Entwicklungs-Phasen ist die Krankheit identisch mit endemischem Kropf. Da sich eine scharfe Grenze zwischen sogenanntem endemischem Kropf und dem was wir als Krebs der Schilddrüse auffassen und bewiesen zu haben glauben, nicht ziehen lässt, so behaupten wir, dass endemischer Kropf und Schilddrüsen-Krebs bei den Salmoniden ein und dieselbe Krankheit ist.

RÉSUMÉ.

L'investigation, dont les pages suivantes sont un compte-rendu, du carcinome de la glande thyroïdienne chez les poissons a été entreprise par le directeur du Gratwick Laboratory dans le cours des recherches du laboratoire sur la nature du cancer chez l'homme. Le Président des États-Unis ayant eu son attention appelée sur ce travail a instruit le bureau des poissons d'y prêter son concours, de sorte que les ressources des États-Unis et de l'État de New York, représentées par ce bureau et le Gratwick Laboratory, étant réunies, il en a résulté une investigation plus étendue de grand intérêt et de grande importance autant pour la pisciculture que pour les recherches sur le cancer.

Bonnet, en 1883, décrit une maladie des branchies chez la truite, laquelle est sans doute identique avec le sujet de ce travail. Cette description est donc la première publication sur ce sujet, quoique la nature de la maladie ne fût pas alors reconnue. Scott en 1891 fut le premier à reconnaître la maladie comme carcinomateuse sans toutefois reconnaître sa relation avec la glande thyroïde. Son origine dans la glande thyroïde fut avancée en premier lieu par Plehn en 1902, elle en fit le diagnostic de l'adéno-carcinome. Pick publia en 1905 la première étude un peu complète sur la structure de ces tumeurs et insista sur leur nature cancéreuse. Gillruth en 1902 le décrit comme une épithéliome ayant siège dans les arcs branchiaux et dit qu'on le trouvait dans la plupart des établissements de pisciculture de la Nouvelle-Zélande. Gaylord commença son étude de la maladie en 1908 et fit un rapport dans lequel il attira l'attention sur la nature infectieuse de la cause. Marine et Lenhart comme résultat de leurs études commencées en 1909 considèrent la maladie comme étant un goître endémique et disent qu'ils n'ont pas trouvé de sujets dans lesquels ils ont trouvé aucun symptôme de cancer.

La maladie est grandement répandue à travers les États-Unis et existe probablement plus ou moins partout où l'élevage artificiel des salmonidées est continué plus loin que dans leur état primitif.

II. Les follicules thyroïdiens chez les salmonidées ressemblent à ceux des mammaliens, mais la glande n'est pas encapsulée ni si limitée dans sa situation. Chez les truites de ruisseaux sauvages les plus grandes collections de follicules sont à peine macroscopiquement visibles, et tout le tissu thyroïdien est placé aux alentours de l'aorte ventrale du côté dorsal entre les premier et troisième arcs branchiaux et ne s'étend pas latéralement le long de ces arcs. Leur distribution est quelque peu moins restreinte que ne l'indique Gudernatsch. On trouve souvent des dépôts irréguliers sous l'épithélium de la fosse jugulaire, mais ils sont rares autre part. Les follicules thyroïdiens des truites sauvages sont de forme régulière, généralement sphériques ou un peu allongés, dans les conditions types et normales ils sont composés d'épithélium généralement aplati, mais dans aucun cas plus haut que cuboïde.

III. Une simple hyperplasie de la thyroïde chez la truite existant dans des conditions sauvages se rencontre assez souvent. Les follicules sont augmentés en nombre, leur forme est plus irrégulière, la substance colloïdale est diminuée, l'épithélium est pour la plupart colonnaire. La même hyperplasie existe aussi chez la truite d'élevage et ne peut être distinguée des premiers développements du carcinome de la thyroïde.

La truite de mer (*Salmo trutta*) dans ses premières années présente aussi quelquefois cette simple hyperplasie, et on trouve même quelques adultes avec un goître colloïdal. La guérison spontanée du carcinome chez le poisson ne résulte pas en goître colloïdal.

IV. On trouve généralement comme première évidence macroscopique de la maladie un foyer d'hyperhémie sur le plancher de la bouche (plancher rouge). Le premier signe visible de tumeur se voit généralement à la jonction des arcs branchiaux. Les tumeurs peuvent s'étendre dans différentes directions, soit vers le plancher de la bouche, soit de chaque côté des ouïes. Des tumeurs indépendantes peuvent se développer dans la fosse jugulaire, région qui contient souvent des dépôts de tissu thyroïdien normal. On trouve la première évidence microscopique de la maladie dans les follicules individuels, généralement dans ceux proches d'un grand vaisseau. Souvent il se fait qu'on trouve à ce degré un petit groupe de follicules altérés entourés par des follicules normaux. L'épithélium est composé de hautes cellules cuboïdes ou en colonnes, le protoplasme et les noyaux prennent un coloris profond. La substance colloïdale est diminuée ou manque complètement, les vaisseaux du stroma sont hyperhémiques. Ceci est suivi par un bourgeonnement de la paroi du follicule, formant de nouveaux follicules isolés, de type irrégulier, et aussi des projections papillaires dans les follicules. Comme la glande n'est pas encapsulée, il se développe un tissu de formation nouvelle entre les plans musculaires et qui remplit aussi les espaces aréolaires. A cette époque on trouve souvent des formes karyokinétiques, l'épithélium est en colonnes hautes; le même follicules contenant souvent plusieurs couches d'épithélium. A ce moment il se peut que la prolifération soit assez développée pour donner lieu à la condition reconnue comme celle du plancher rouge. L'os, le cartilage et le muscle, tout est envahi. La tumeur ne cherche plus le chemin de moindre résistance. Dans la période où la tumeur est visible les variations dans le caractère de la prolifération sont remarquables. Tous les différents types peuvent exister dans la même tumeur. On peut les diviser en alvéolaires, tubulaires et solides, ainsi que combinées avec les types papillaires et cystiques. On voit souvent de petites masses adénomateuses d'apparence maligne envahissant et infiltrant le tissu thyroïdien qui apparaît moins malin aux alentours. Il arrive quelquefois qu'on trouve des îlots de tissu thyroïdien normal dans les espaces et cavités des os, tandis que le tissu environnant a été complètement remplacé par le thyroïde carcinomateux. Une infiltration vraie de l'os, du cartilage, de la paroi vasculaire, du muscle et de la peau a été démontrée. Parfois on trouve des tumeurs qui présentent l'apparence des soi-disant tumeurs sarco-carcinomateuses de la thyroïde chez les mammifères; un arrière-plan de cellules en fuseau ressemblant à un sarcome avec, ça et là, des alvéoles. Les croissances sur la pointe de la mâchoire sont soit des implantations, soit des métastases. Ayant trouvé une tumeur de la pointe de la mâchoire pareille à une tumeur thyroïdienne primaire, nous en avons fait une étude spéciale, dont il résulte que cette formation métastatique a probablement lieu à un point blessé. Dans un cas de tumeur trouvée dans la paroi intestinale nous avons un cas certain de tumeur métastatique, cette tumeur fut trouvée à l'extrémité inférieure des intestins, elle infiltrait d'un vrai tissu carcinomateux thyroïdien le tissu "muscularis mucosa" de la paroi intestinale. Ce tissu se composait de grands follicules irréguliers doublés d'épithélium en colonne,

contenant parfois de la substance colloïde. Il y avait des parties de la tumeur qui présentaient l'apparence des tumeurs primaires les moins malignes. Le caractère de cette tumeur et la région où on la trouva démontra sans aucun doute qu'elle était de caractère métastatique. Une comparaison des différents types de thyroïde carcinomateuse chez les salmonidées nous démontra qu'on peut les classer approximativement sous les trois groupes proposés par Langhans pour le carcinoma de la thyroïde chez les mammifères, c'est-à-dire struma proliférant, struma carcinomateux, et papillome malin.

V. Trois cas de la maladie ont été trouvés chez les poissons sauvage aux États-Unis. (1) Chez une truite de ruisseau qui peut avoir été distribuée par un établissement de pisciculture; (2) chez un Laveret (*Coregonus*) qui ne peut être élevé ni nourri artificiellement; (3) chez un saumon de lac (*Salmo sebago*).

VI. La maladie a été observée chez 16 espèces ou hybrides des salmonidées.

La formation géologique aux sources des eaux dans lesquelles on trouve la maladie semble n'avoir rien à faire avec son origine, de même que le contenu dissous dans l'eau.

La maladie est généralement endémique, rarement épidémique. On la trouve dans les viviers et bassins, quelle que soit leur construction, où les poissons sont gardés, élevés et nourris avec la nourriture protéidienne ordinaire de la pisciculture, c'est à dire, foie, cœur, poumons et autres viandes crues. Elle paraît avoir une tendance à augmenter en descendant un cours d'eau. Les hybrides du saumon de la côte du Pacifique semblent spécialement susceptibles et présentent un grand pourcentage de cas. Quand la maladie est endémique son cours est lent et chronique, avec une mortalité difficile à déterminer à cause de complications avec des infections secondaires ou terminales at autres causes de mort. Le nombre des tumerus varie énormément et augmente avec l'âge du poisson. Des tumeurs visibles macroscopiquement n'ont pas été vues dans des poissons de moins de 5 mois. Une anémie et cachexie, souvent extrême, accompagne généralement la maladie, mais cette condition peut manquer complètement. L'immunité se voit d'une manière remarquable, non seulement parmi les espèces, comme chez les truites de mer (*Salmo trutta*), mais aussi parmi certaines bandes contenant des espèces susceptibles. Quand des poissons affectés sont déplacés, soit dans un autre vivier non infecté ou mis dans des conditions sauvages, un mouvement rétrograde et même une guérison a lieu assez souvent.

VII. Des truites de ruisseau, quoique ayant été nourries pendant plusieurs mois de tumeurs de poisson et même de cancer humain, n'ont présenté aucune évidence de maladie qu'on ait pu attribuer à cette nourriture. De même, des truites susceptibles quoiqu'ayant été gardées dans de l'eau stagnante contenant de la matière de tumeur de truite, ou avec des poissons infectés dans de l'eau circulant non renouvelée, ont, elles aussi, donné un résultat négatif. La tumeur de poisson n'a pas encore été transplantée avec succès, quoique des greffes ont un peu grandi et n'étaient pas encore nécrotiques au bout du troisième mois. L'extrait de la tumeur est très toxique quand on l'injecte dans la région thyroïdienne ou autre part. Des truites de ruisseau venues d'endroits non habités et enfermées dans des viviers de ciment et nourries avec du cœur et du foie crus ont développé la maladie de manière à ce qu'elle fût visible microscopiquement au bout de la première année et un carcinome visible macroscopiquement

entre la première et deuxième année. La cuisson de la nourriture retarde la marche de la maladie. Une rétrogradation spontanée semble avoir lieu dans un grand pourcentage des poissons ainsi nourris au bout de la deuxième année. Des truites semblables nourries avec du poisson de mer, avec de la nourriture végétale ou avec une combinaison de moules et d'asticots vivants, retiennent leurs thyroïdes normaux.

VIII. Les sels de n'importe lequel des éléments suivants: iode, mercure ou arsenic dissous dans l'eau habitée par les poissons, interrompt le progrès de la maladie et ramène l'épithélium thyroïdien à une condition pour ainsi dire normale. Le résultat se produit d'une manière visible au bout de quelques jours. Ce traitement agit sur les tumeurs visibles de manière que leur grosseur peut être vite diminuée. L'iode et le mercure agissent même quand ils sont dilués dans des millions de parties d'eau. L'iode est effectif quand on l'introduit dans le système digestif aussi bien que dans l'eau. Des résultats négatifs furent obtenus avec l'administration du thymol des deux manières.

IX. L'administration, à des chiens, de la boue et de l'eau des viviers où le carcinome était endémique, montra d'une manière suggestive que la boue et l'eau contenaient un agent capable de produire des changements bien marqués dans la thyroïde. Des raclures d'intérieur de vieux bassins à poisson dans lesquelles le carcinome de poisson a été continuellement reproduit donnèrent des résultats positifs. Pendant six mois on donna à boire à quatre chiens de l'eau dans laquelle ces raclures avaient été macérées. Tous développèrent une hyperplasie thyroïdienne marquée et trois d'entre eux des thyroïdes grossis. Les thyroïdes de trois autres animaux de contrôle à qui on donna la même eau, mais bouillie, restèrent de grandeur normale. Deux d'entre eux étaient normaux comme structure, tandis que le troisième montrait quelques traces d'hyperplasie probablement causées par une expérience antérieure.

Des rats qui avaient été nourris avec la boue et l'eau prises des viviers où il y avait le carcinome et qui avaient été transportés une journée entière en chemin de fer, donnèrent un résultat négatif. Tandis que d'autres auxquels fut donnée de l'eau avec raclures de bassins à poisson également transportée, produisirent des résultats semblables à ceux trouvés chez les chiens, mais à un degré moins marqué.

X. Dans les thyroïdes hyperplastiques des quatre chiens dont trois étaient jeunes, auxquels fut donnée la boue et l'eau de vivier ou de l'eau contenant des raclures de bassins, on a trouvé des vers nématodes minuscules directement sous la capsule ou dans la substance du thyroïde. Les vers étaient entourés de tubercules de tissu conjonctif. Dans deux cas seulement des restes de vers nématodes furent trouvés dans la région thyroïdienne de quelques truites, dans ces cas le carcinome était en état de rétrogradation. Si ces vers ont une signification étiologique, ce ne peut être que simplement comme porteurs de l'agent causatif.

CONCLUSIONS.

1. La maladie connue sous les noms de maladie des branchies, tumeur thyroïdienne, goître endémique ou carcinome de la thyroïde chez les salmonidées, est une tumeur maligne.

2. La maladie se présente chez les poissons vivant en liberté dans des régions peuplées.

3. Quand elle s'introduit dans un établissement de pisciculture elle devient endémique et même quelquefois épidémique.

4. Des poissons normaux pris loin des habitations peuvent contracter la maladie quand on les place dans un vivier où elle est endémique.

5. Le nourrissage avec des produits animaux protéidiens non cuits accélère le développement, tandis que les mêmes produits cuits retardent sa production. Mais le nourrissage seul n'est pas une cause efficace. Il faut le combiner avec un agent transmis probablement par la nourriture ou l'eau, ou peut-être par les deux.

6. En raclant la surface intérieure des bassins en bois dans lesquels la maladie est endémique, on peut acquérir un agent qui, par son action sur la thyroïde des mammifères quand on l'administre dans l'eau potable, est très probablement la cause de la maladie chez les poissons gardés dans ces bassins.

7. On peut détruire l'agent en le bouillant.

8. L'état des poissons, dans n'importe quel degré de la maladie, est amélioré favorablement par l'addition à l'eau, de mercure, d'iode, ou d'arsenic en quantité nécessaire.

9. L'effet du mercure, de l'arsenic et de l'iode sur le carcinome de la thyroïde chez les poissons, et subséquemment les résultats positifs de cet usage de métaux dans le cancer des mammifères, font croire à une relation thérapeutique entre les métaux et le carcinome.

10. Certaines espèces de salmonidées offrent une résistance naturelle presque complète à la maladie.

11. Certains groupes de poissons d'espèces susceptibles montrent un degré d'immunité très élevé contre la maladie.

12. Une guérison spontanée a lieu dans un pourcentage considérable de sujets.

13. Quand on change les sujets du local où la maladie est endémique à des conditions naturelles, ou quand on leur donne une nourriture plus naturelle, on remarque également une augmentation du pourcentage des guérisons spontanées.

14. La guérison spontanée semble accorder un certain degré d'immunité contre la récidive.

15. Le pourcentage des guérisons spontanées semble être plus grand dans les premiers degrés de la maladie que plus tard.

16. La susceptibilité à la maladie semble augmenter avec l'âge du poisson au moins jusqu'à l'âge de cinq ans.

17. Au bout de cinq mois on a remarqué un développement thyroïde et autres changements qui présentent un tableau type de goître parenchymateux diffus chez les mammifères auxquels on a donné à boire de l'eau dans laquelle avaient été suspendues des raclures de bassins dans lesquelles la maladie était endémique. Les animaux employés comme contrôle qui recevaient la même eau bouillie n'ont pas développé de changements thyroïdiens. Que ces développements et changements sont les premiers degrés chez les mammifères de la même maladie qui a lieu chez les poissons habitant les bassins d'où les raclures ont été prises, voilà une déduction que nous croyons que des expériences plus étendues justifieront.

18. La maladie est endémique dans un grand pourcentage des établissements de pisciculture aux États-Unis.

19. Que la maladie se présente chez le poisson sauvage, qu'on peut l'introduire dans des établissements de pisciculture, qu'elle se localise dans certains bassins ou cours d'eau, la manière dont elle se répand, sa transmission aux mammifères, le bon résultat obtenu dans le traitement de la maladie avec les trois germicides inorganiques bien connus, la destruction de l'agent par la chaleur, le phénomène de la guérison spontanée et de l'immunité, tout semble indiquer que l'agent provocateur de la maladie est un organisme vivant.

20. Jusqu'à présent rien n'indique que la maladie peut être transmise directement d'individu à individu.

21. Dans beaucoup de ses phases la maladie est identique avec le goître endémique. Comme il ne semble pas y avoir de point de démarcation entre le goître endémique et ce que nous croyons avoir démontré être un cancer de la thyroïde, il nous semble que nous pouvons dire que le goître endémique et le carcinome chez les salmonidées sont la même maladie.

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FIG. 1.—From Scott's "Cancer in Fish," 1891. Floor of mouth of *Salmo fontinalis*, showing protrusion of tumor in pharyngeal floor.



FIG. 2.—Drawing from microscopic section showing acini with infiltration of surrounding structure of individual cells. After Scott.



FIG. 3.—Rainbow trout. Redrawn from Gilruth's colored original, 1902. Large tumor on each side of branchial junction. Gill fringe distended on surface of lower one.



FIG. 4a.—Yearling hybrid salmon. Massive tumors and marked emaciation. Lot 1988a.



FIG. 4b.—Two year old *Salmo sebago*, extreme emaciation. Lot 1950.

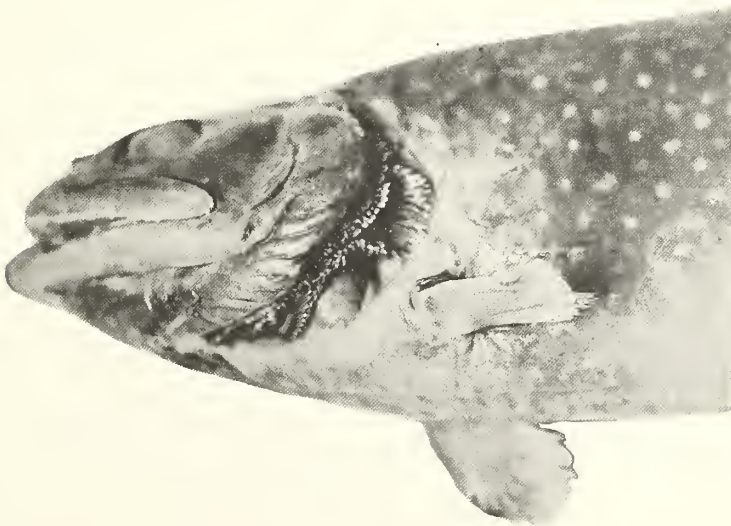


FIG. 4.—*Salmo fontinalis* 2 years old. First external evidence of tumor in base of muscular structure of isthmus, showing marked infiltrative tendency of growth.

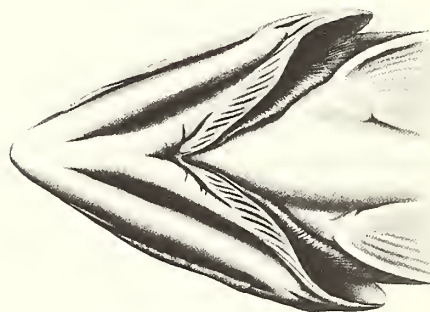
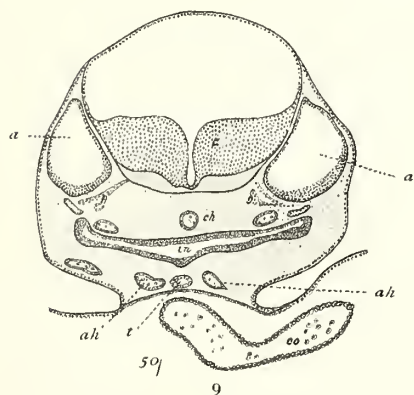
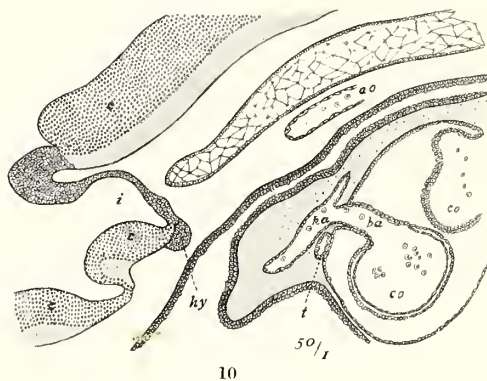
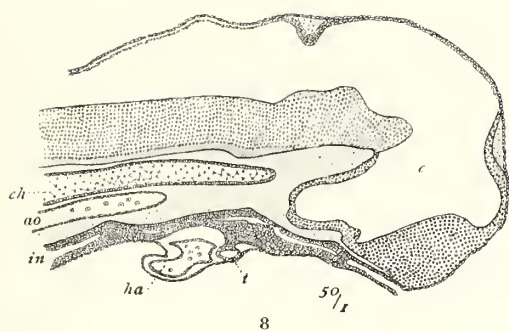
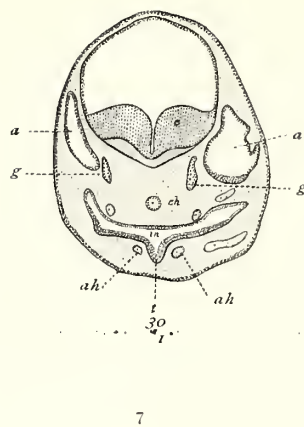
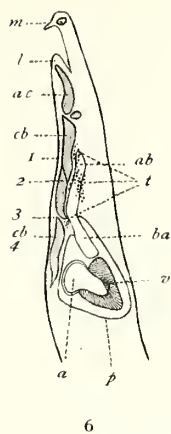
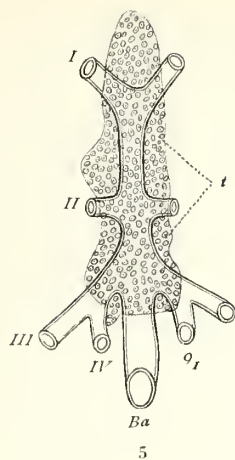


FIG. 5.—Redrawn from Maurer, 1886. Thyroid of a trout 20 cm. long; shown in its relation to the branchial arteries, seen from the ventral side.

FIG. 6.—Redrawn from Maurer. Median section to show distribution of thyroid about the ventral aorta in a trout 2.5 cm. long.

FIG. 7.—Redrawn from Maurer. Cross section of the head of a trout embryo of 30 days, showing earliest evagination of pharyngeal epithelium to form the thyroid.

FIG. 8.—Redrawn from Maurer. Median section through head of trout embryo of 35 days. Primary thyroid vesicle (*t*) still attached to parent epithelium by pedicle.

FIG. 9.—Redrawn from Maurer. Cross section of a trout embryo of 35 days. Primary thyroid vesicle (*t*) separated from parent epithelium.

FIG. 10.—Redrawn from Maurer. Median section through head of trout embryo of 41 days. Compared with figure 8, it shows that the elongated primary thyroid vesicle (*t*) has moved backward and now lies ventral to the aorta.

FIG. 11.—Drawing showing gross appearance of jugular pit from below.

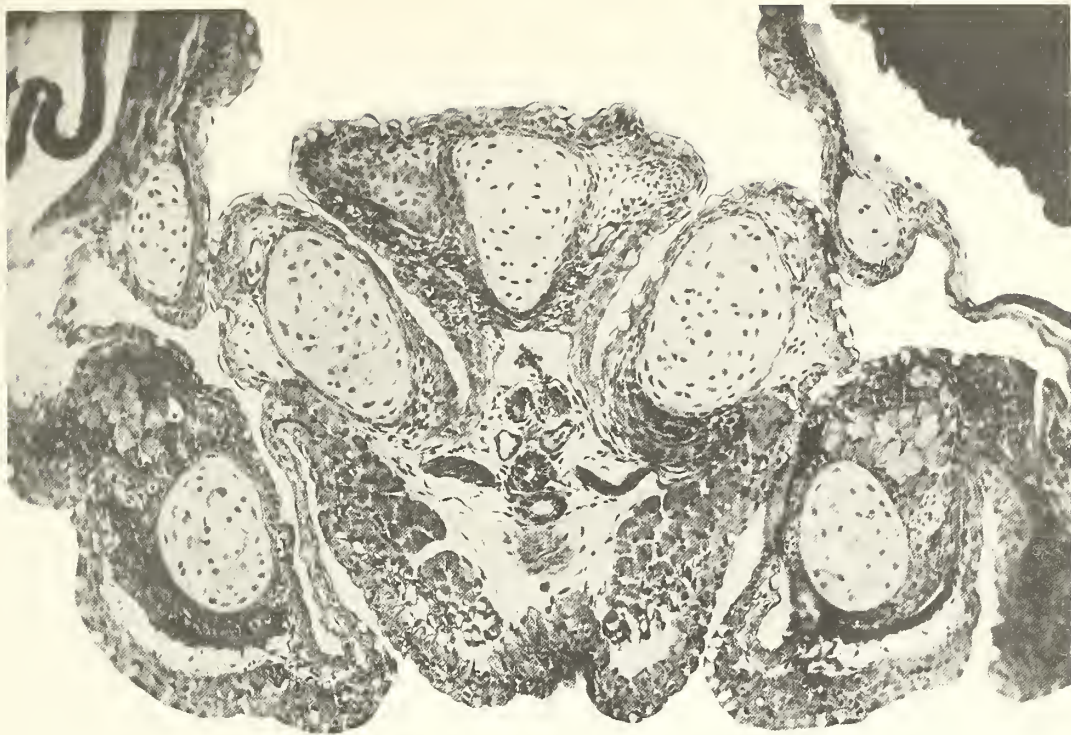


FIG. 12.—*Salvelinus fontinalis* in sac stage, hatched a few days; showing relation of thyroid follicles to invagination which becomes jugular pit. X86.

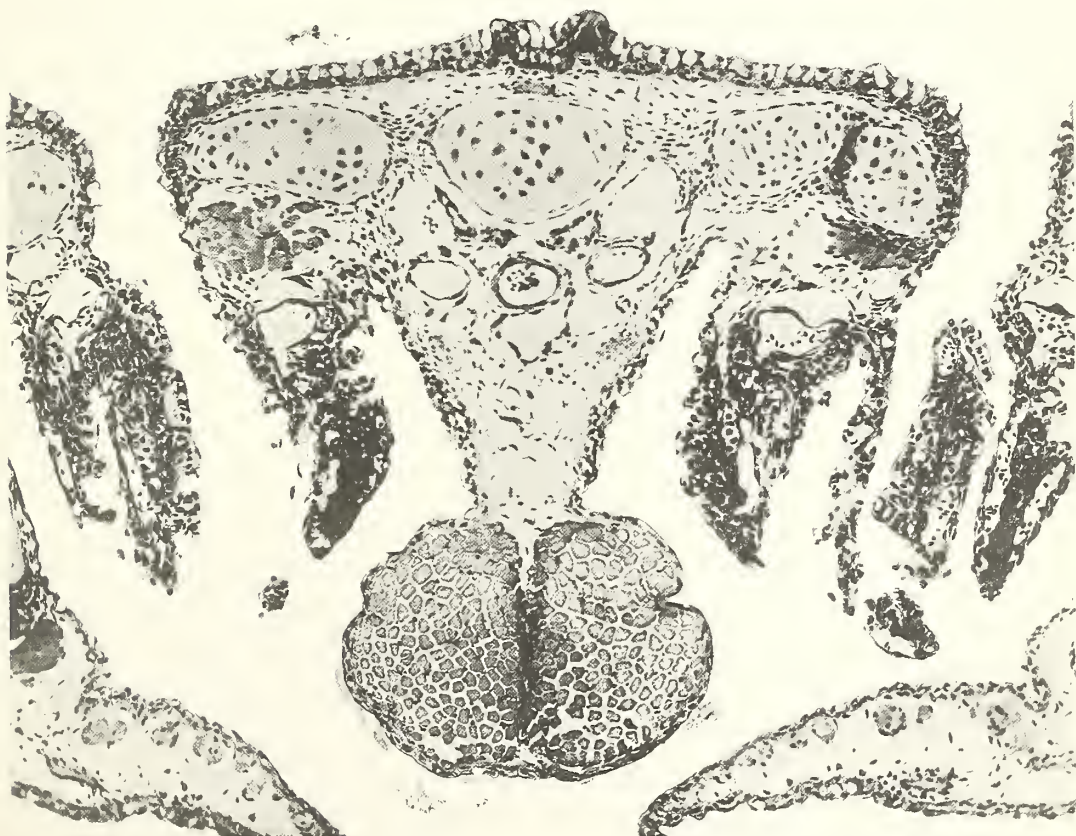


FIG. 13.—Brook trout fry showing early thyroid follicles containing colloid material. X86.



FIG. 14.—Scotch sea trout. Longitudinal section of lower jaw above showing normal thyroid follicles; below, in the right hand corner, an isolated misplaced thyroid follicle lying adjacent to the epithelium of the pit. X10.

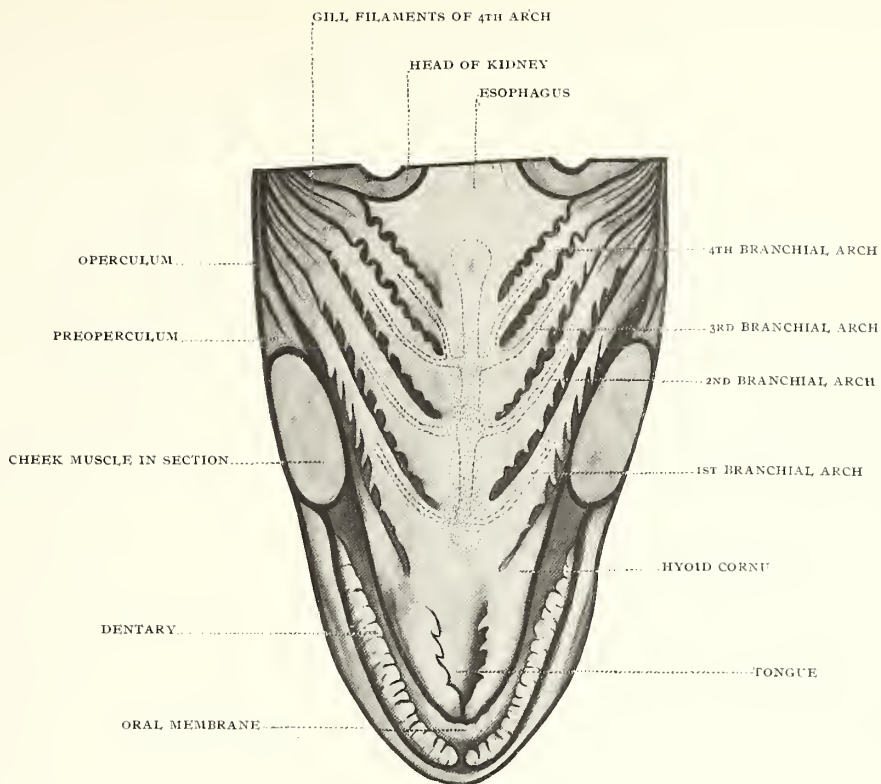


FIG. 15.—Composite picture of lateral and longitudinal distribution of normal thyroid in the Salmonidae, with vessels.

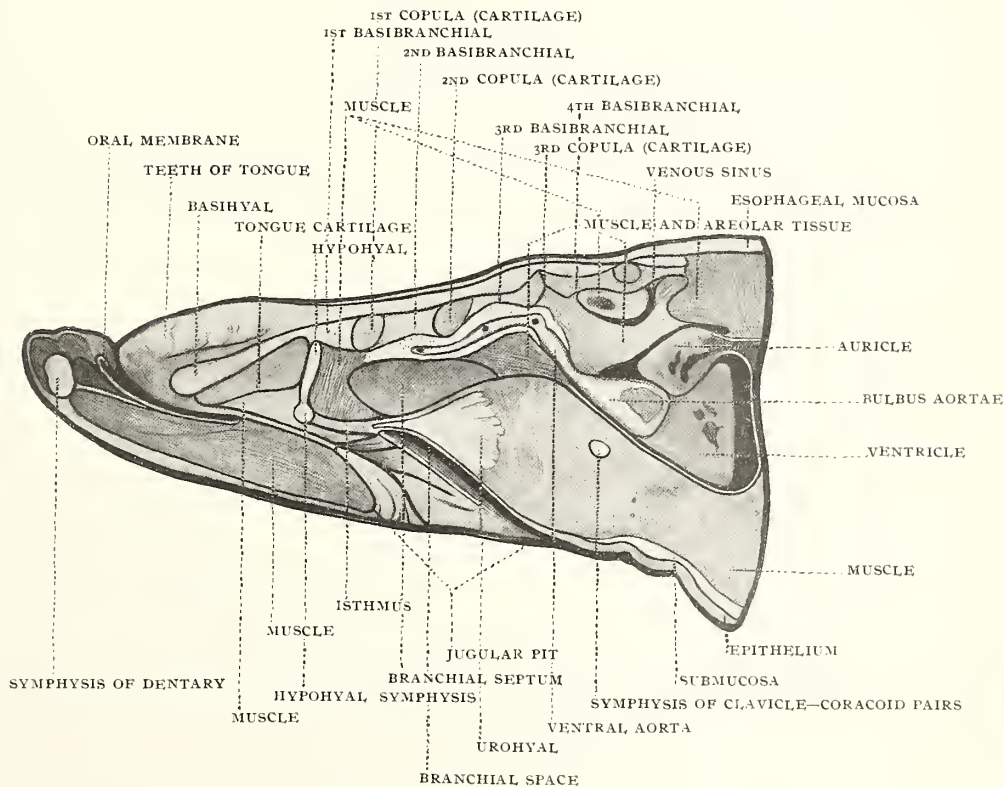


FIG. 16.—Longitudinal and dorso-ventral distribution of thyroid in the Salmonidae.



FIG. 17.—Wild brook trout from Au Sable River; 8.2 cm. long; cross section showing distribution of normal thyroid. X86.



FIG. 18.—Algonquin wild brook trout; simple hyperplasia; high cuboidal epithelium reduction in some follicles and absence in others of colloid. Distinct hyperemia about follicles; increased amount of thyroid. X86.



FIG. 19.—Domesticated Scotch sea trout fingerling; normal thyroid structure. X86.



FIG. 20.—Domesticated Scotch sea trout fingerling; same hatchery as above, showing simple hyperplasia, increased number of thyroid follicles; epithelium high cuboidal and low columnar; colloid diminished. X86.

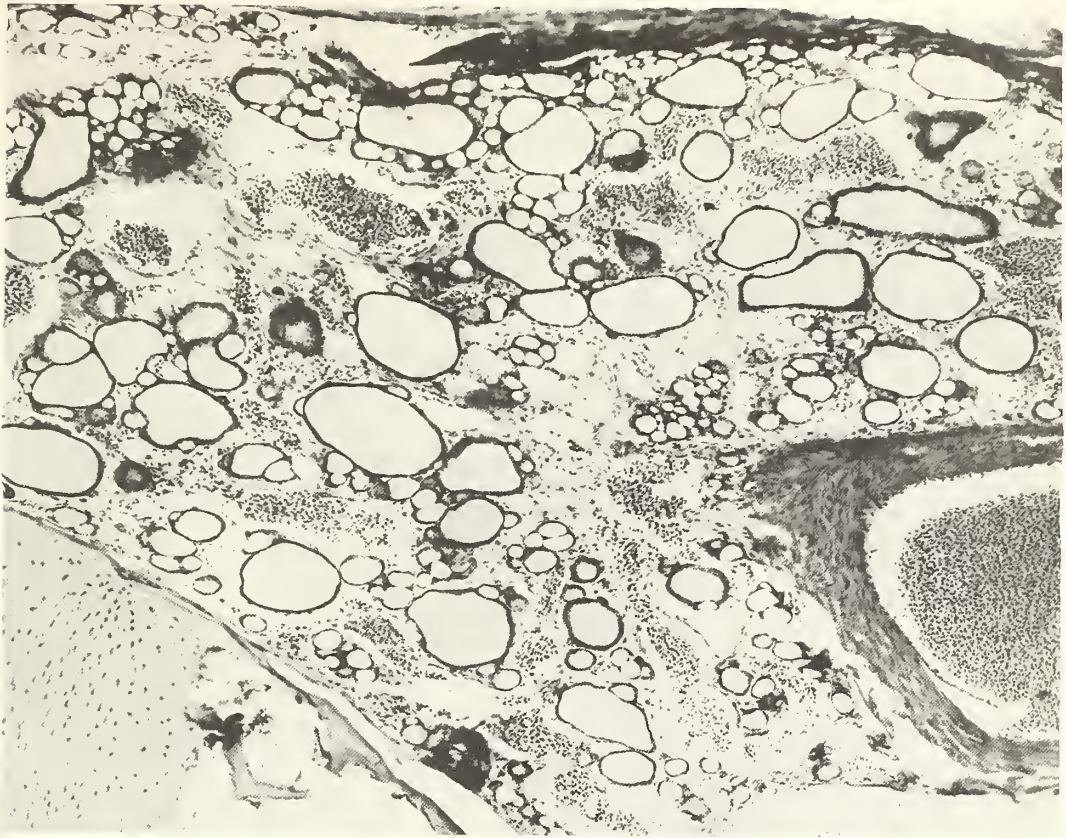


FIG. 21.—Adult domesticated sea trout, normal thyroid structure. X86.

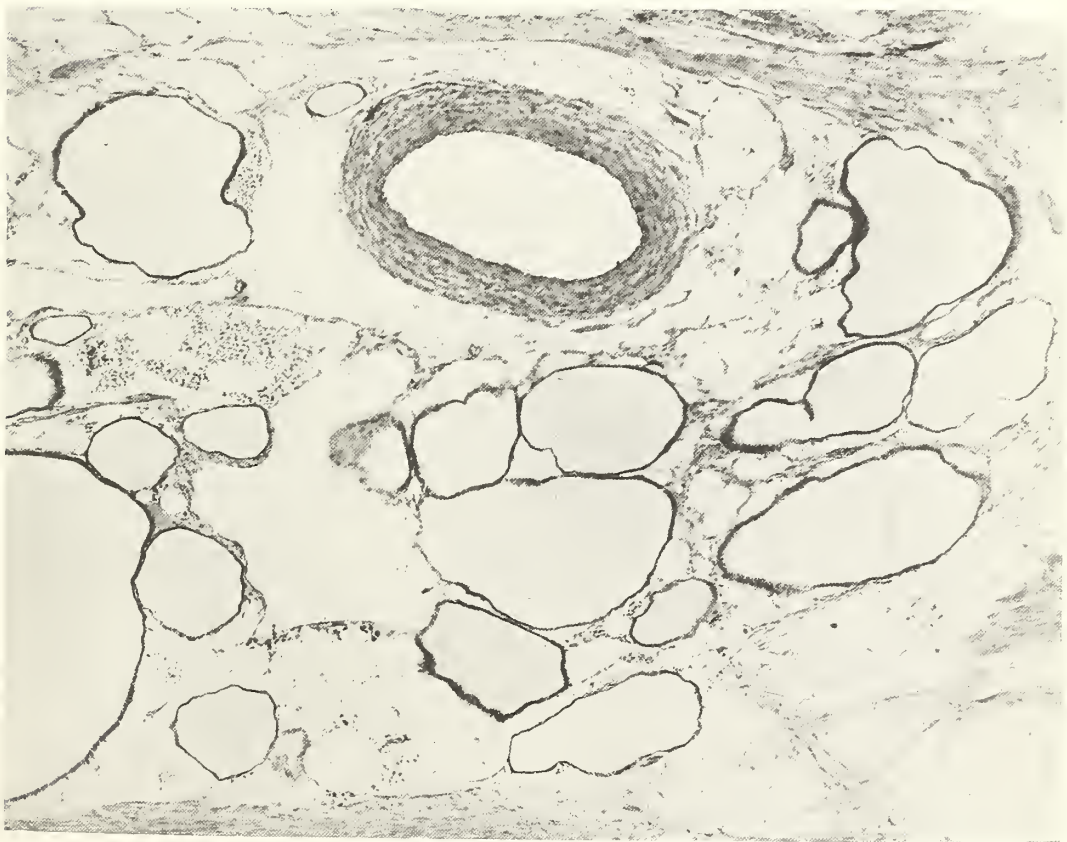


FIG. 22.—Adult domesticated Scotch sea trout; colloid goiter. X86.



FIG. 25.—Brook trout, showing rectal metastasis of thyroid origin (Anal fin pinned back to show tumor.)



FIG. 24.—Brook trout, showing large round tumor springing from the jugular pit.



FIG. 23a.—A view of normal floor of mouth of adult brook trout.



FIG. 23.—Hyperemia of floor of mouth of adult brook trout, so-called red floor. First macroscopic evidence of hyperplasia or carcinoma of thyroid.



FIG. 26.—Brook trout, showing massive thyroid tumor in the mouth cavity, springing from the floor of the month.



FIG. 27.—Two year old brook trout, showing massive tumor filling the entire gill space.



FIG. 28.—Brook trout, showing tumor mass at the tip of the lower jaw.



FIG. 29.—Brook trout showing nodular growths in floor of mouth.



FIG. 30.—Brook trout showing numerous tumor vegetations in floor of mouth.



FIG. 31.—Section of floor of mouth showing thyroid follicles growing in epithelium above basal membrane. X70.



FIG. 32.—Section from floor of mouth showing histological structure of papillary growths found in floor of mouth illustrated macroscopically by figure 30. X94.

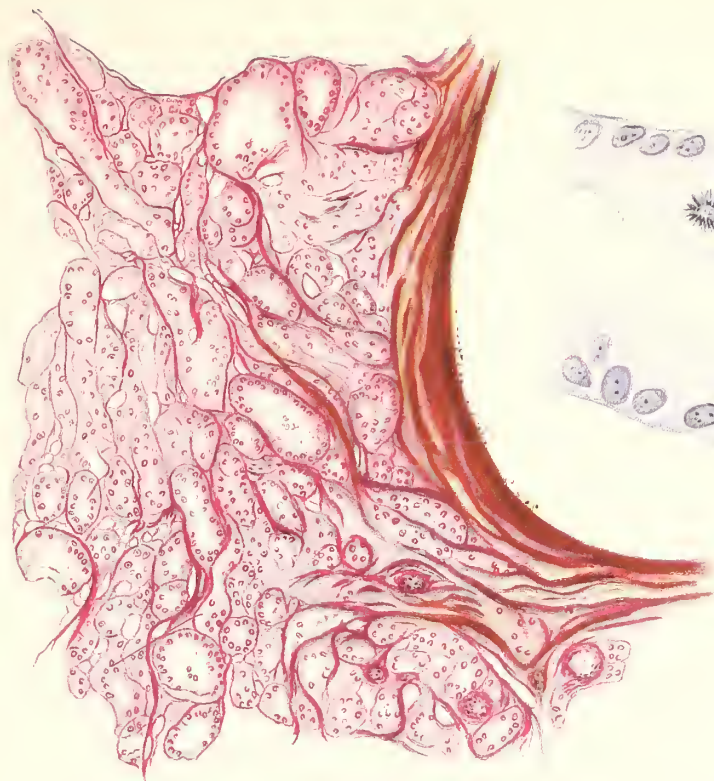


FIG. 33.—Infiltration of aortic wall by alveolar carcinoma of thyroid.

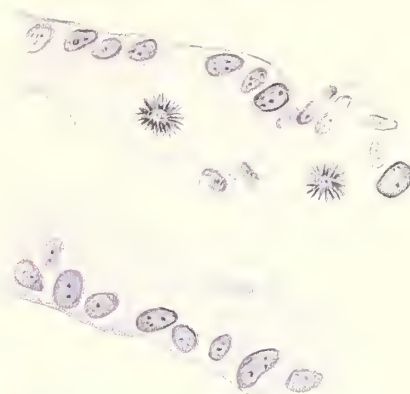


FIG. 35.—Same section, higher power. Tubular structure with mitoses.

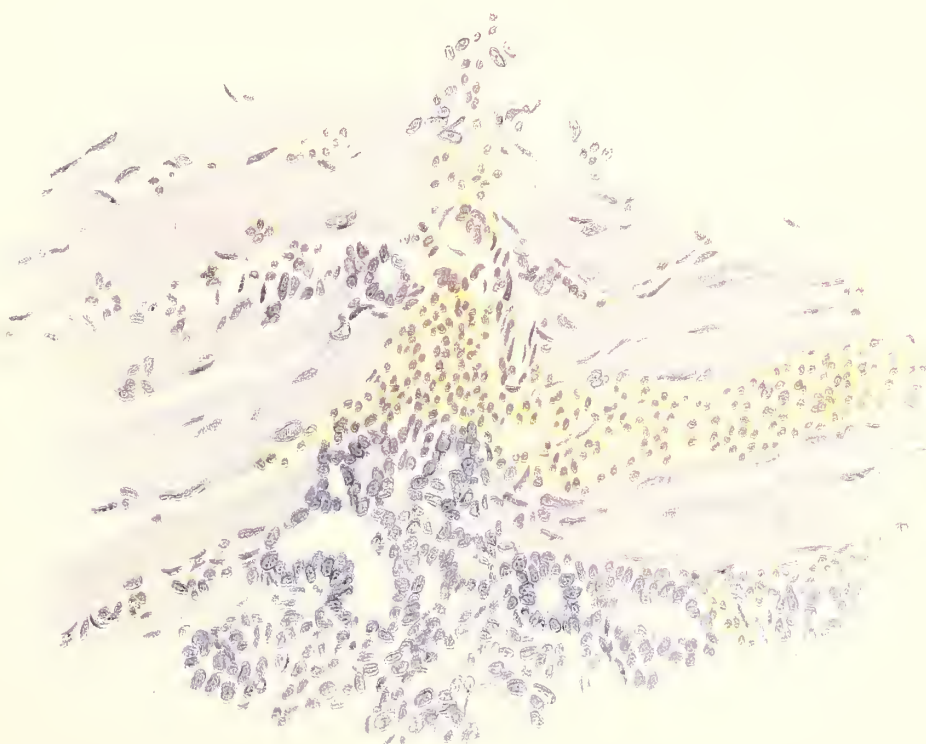


FIG. 34.—Drawing showing infiltration of surrounding structures in the early stage of carcinoma of thyroid.

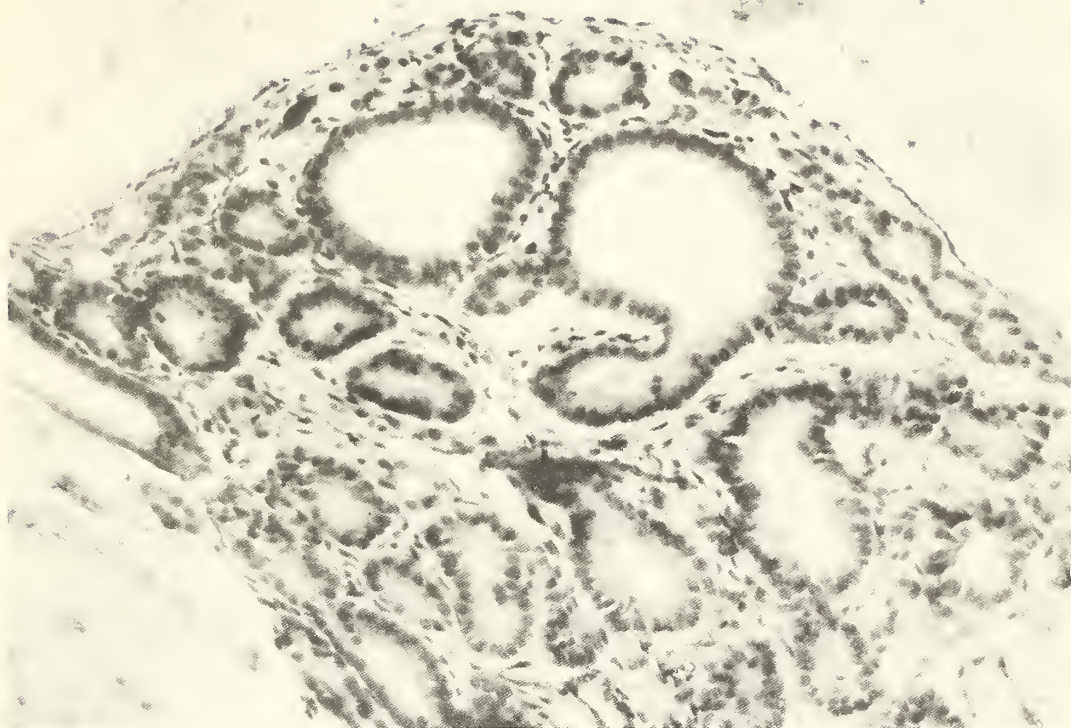


FIG. 36.—High power section of the early stages of the disease showing formation of new follicles by budding of the alveoli with subsequent splitting off. Note karyokinetic figures. X200.



FIG. 37.—Cross section of the lower jaw showing growth infiltrating the surrounding structures. X10½.

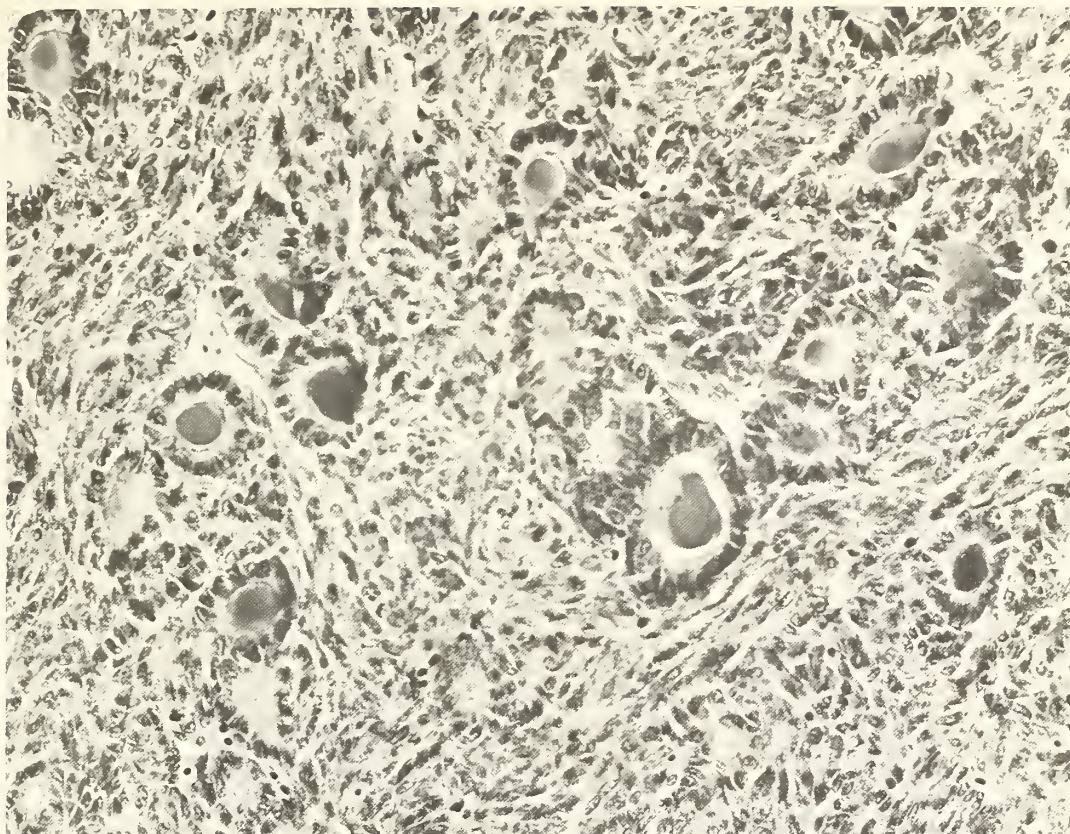


FIG. 38.—Section showing the mixed type. In the center a few follicles containing colloid with background of spindle cells. X280.

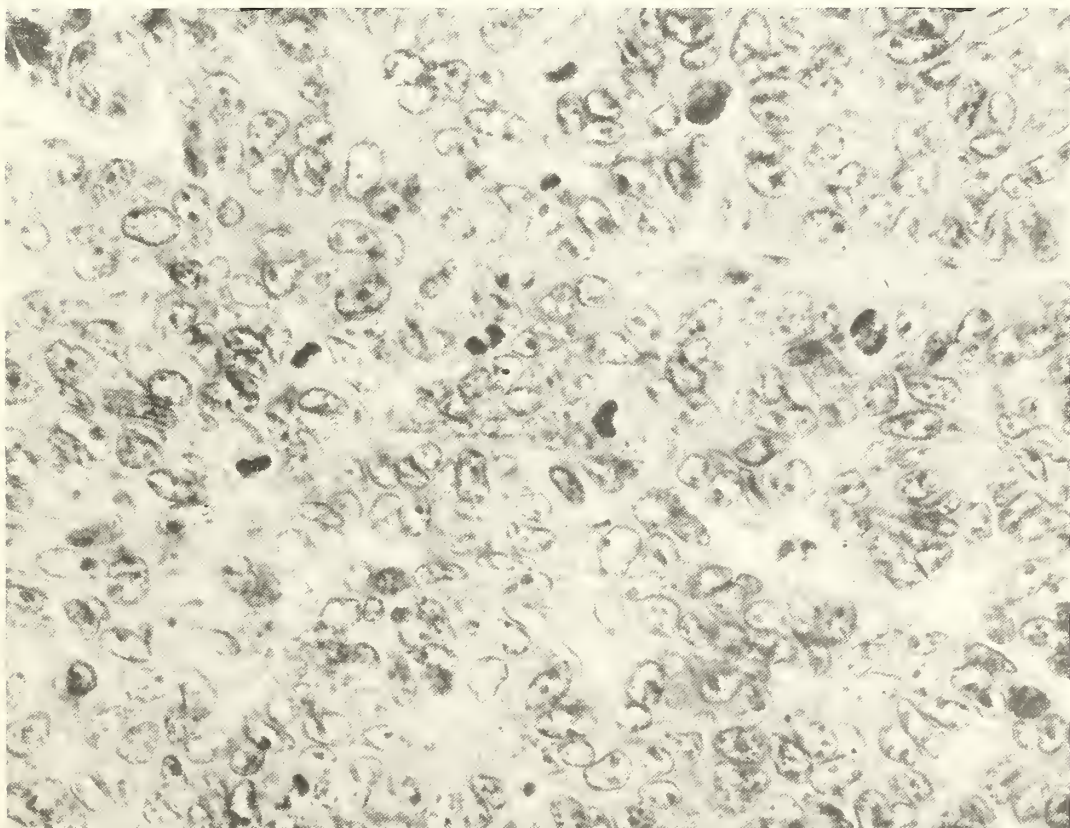


FIG. 39.—Section of tumor presenting the picture of proliferating struma of Langhans, showing numerous karyokinetic figures. X600.



FIG. 40.—Section of lower jaw showing nodular development in various portions of the tumor mass. X10.

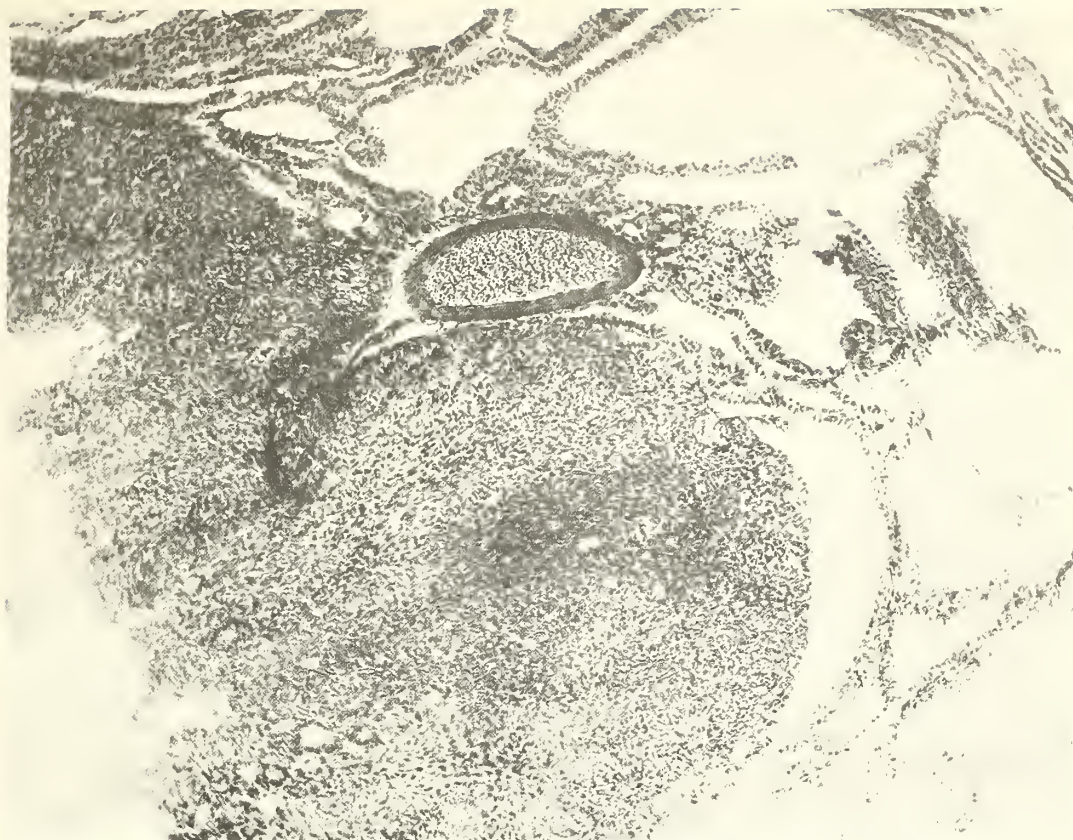


FIG. 41.—High power section from figure 39 of a nodule showing closely packed spindle and oval cells with deeply staining nuclei, with here and there an attempt at alveolar arrangement. X94.

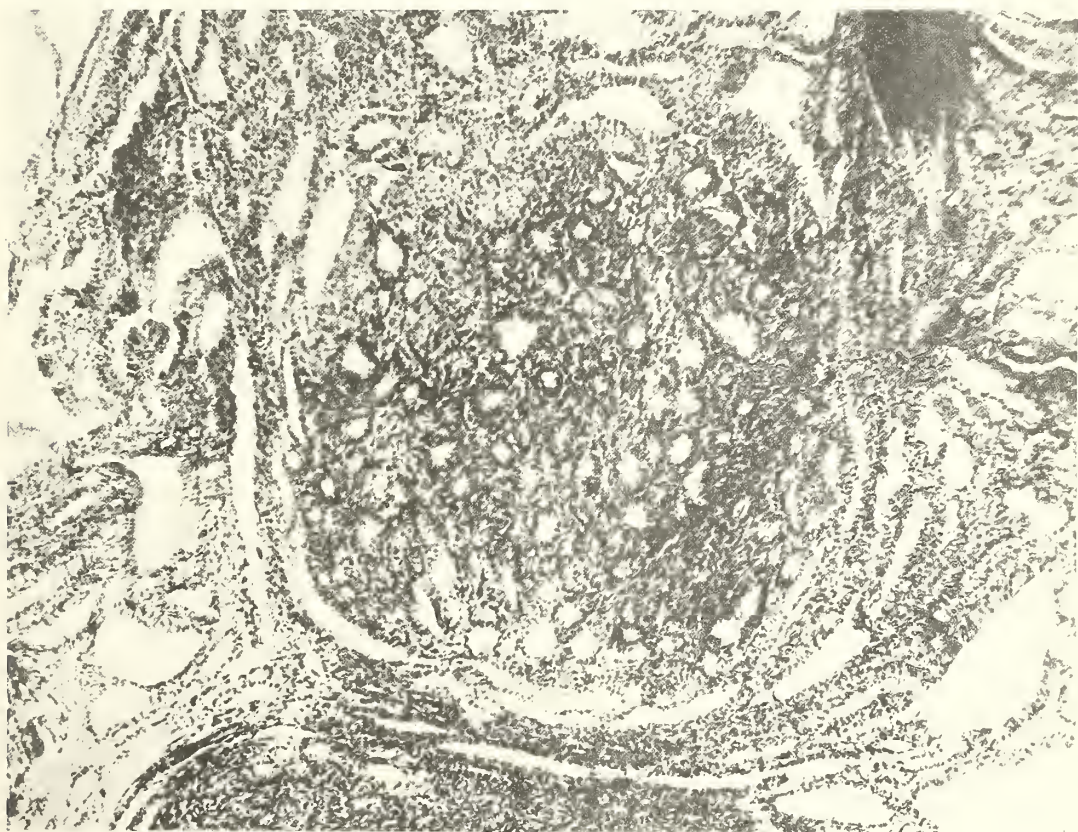


FIG. 42.—High power section from figure 39 showing a small, distinct nodule of adenomatous type lying in loose alveolar structure. X94.

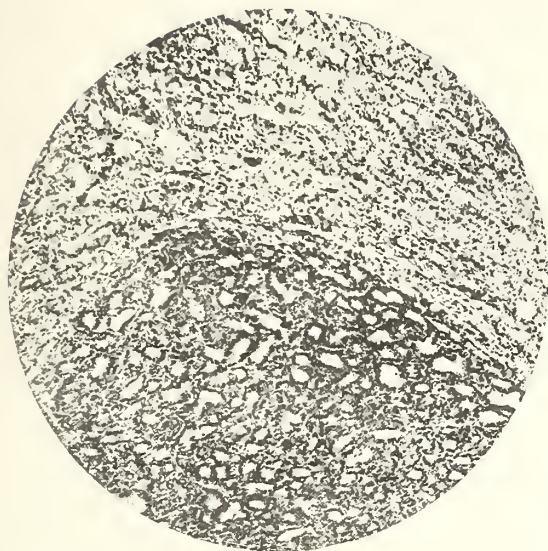


FIG. 43.—Section showing intensive nodular growth with concentric compression of the surrounding tumor tissue. X40.



FIG. 44.—Section showing individual follicles of more malignant type infiltrating surrounding tumor tissue. X130.

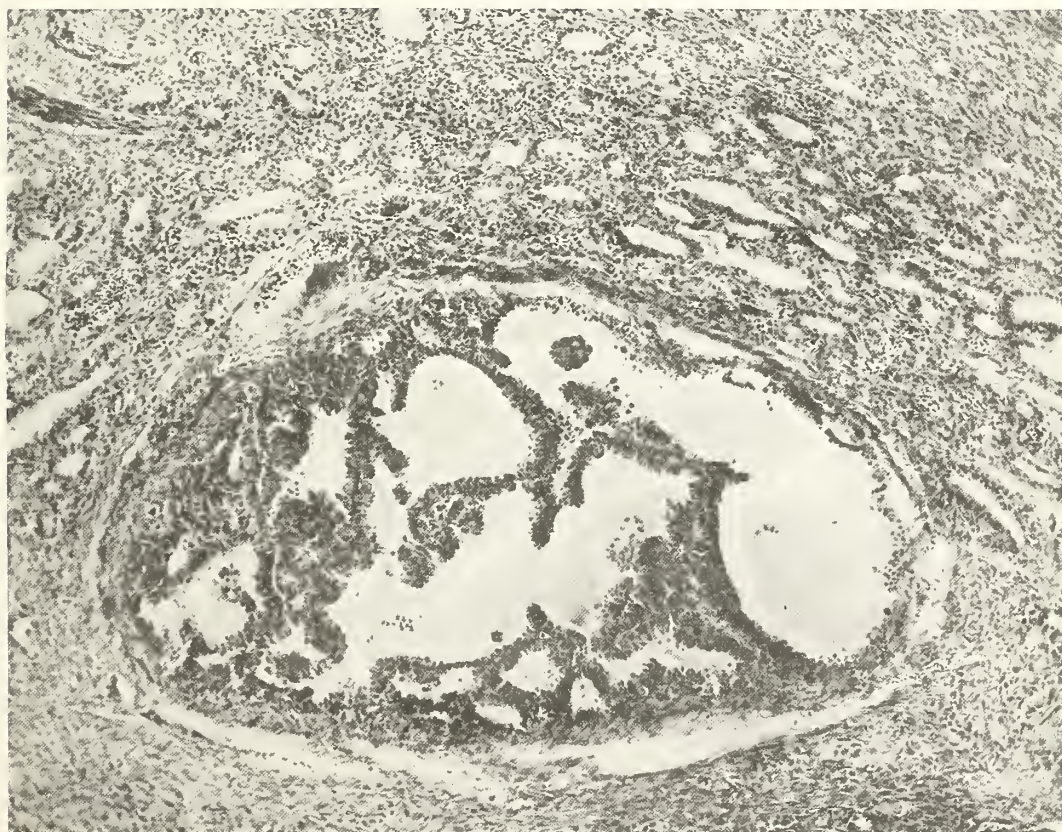


FIG. 45.—Section showing encapsulated nodule of papillar type lying in tumor tissue of alveolar type. X94.

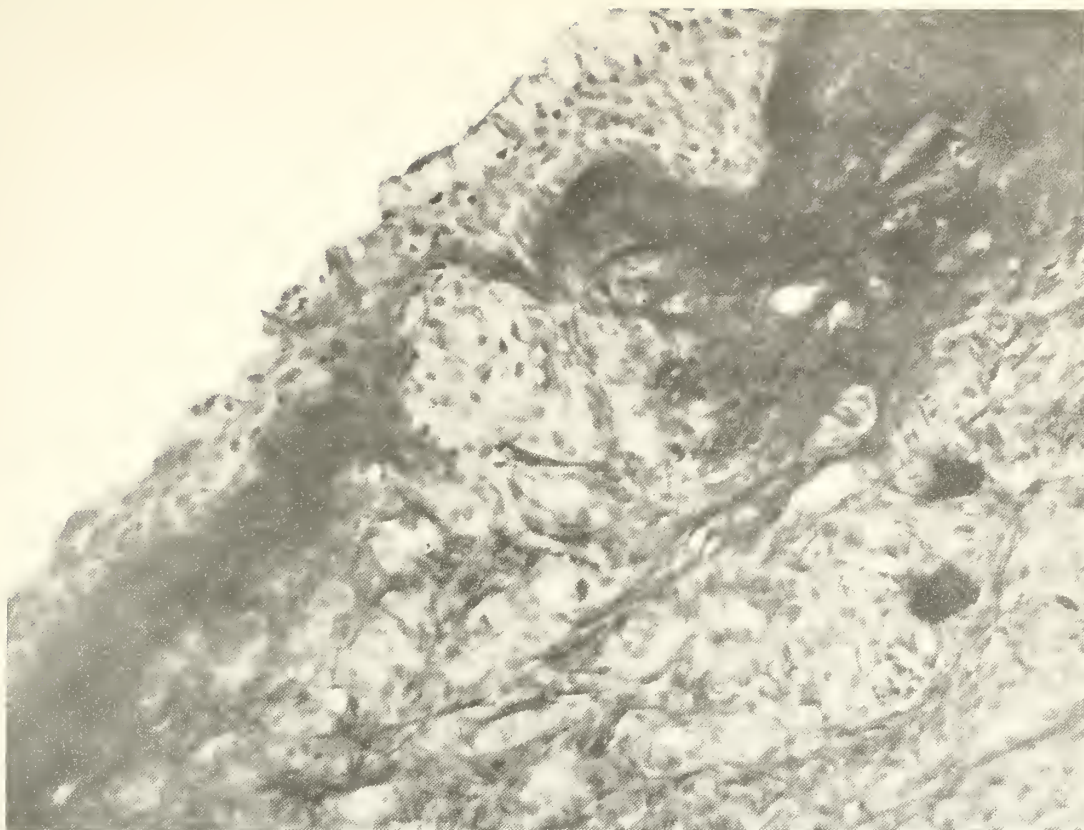


FIG. 46.—Section of floor of the mouth showing tumor cells infiltrating and destroying basal membrane. Splitting of elastica. X260.

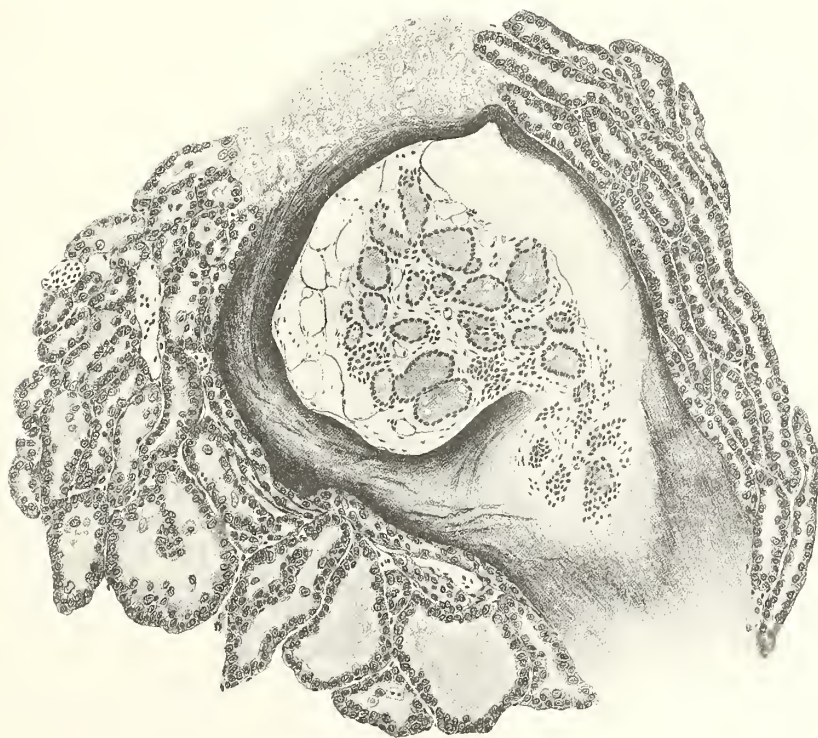


FIG. 47.—Drawing of section showing normal thyroid tissue isolated in a bone space surrounded by tumor tissue.

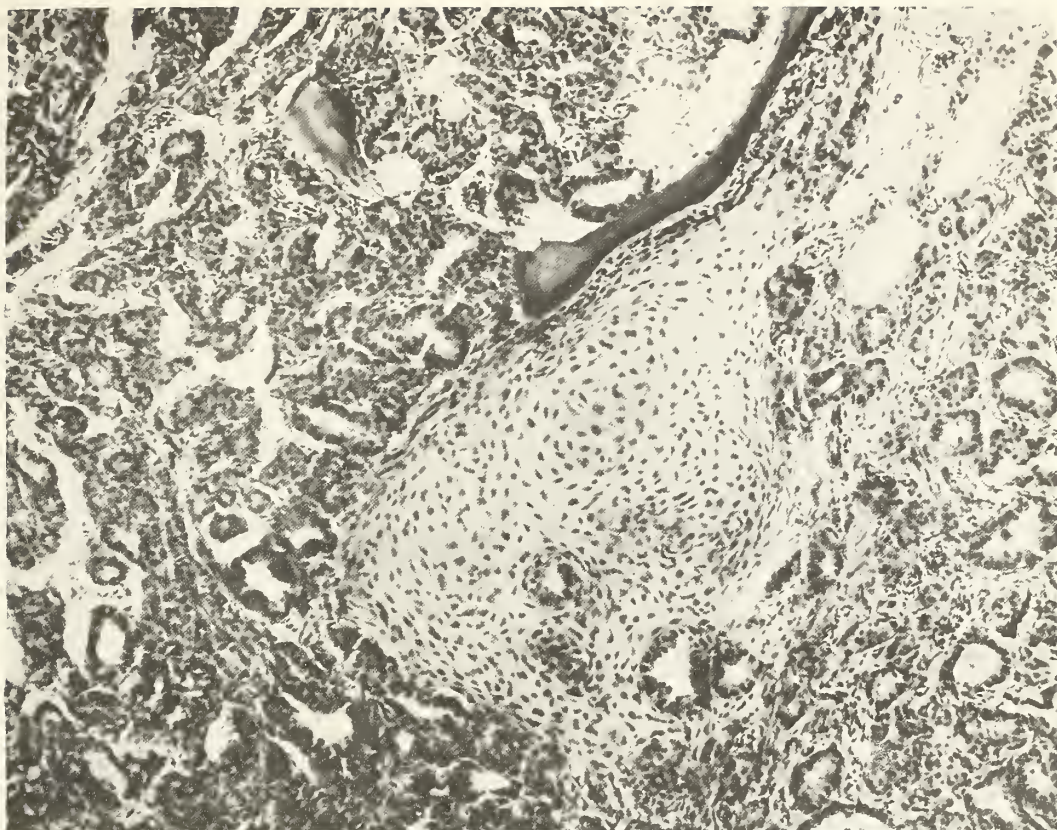


FIG. 48.—Section showing infiltration and destruction of cartilage. X136.

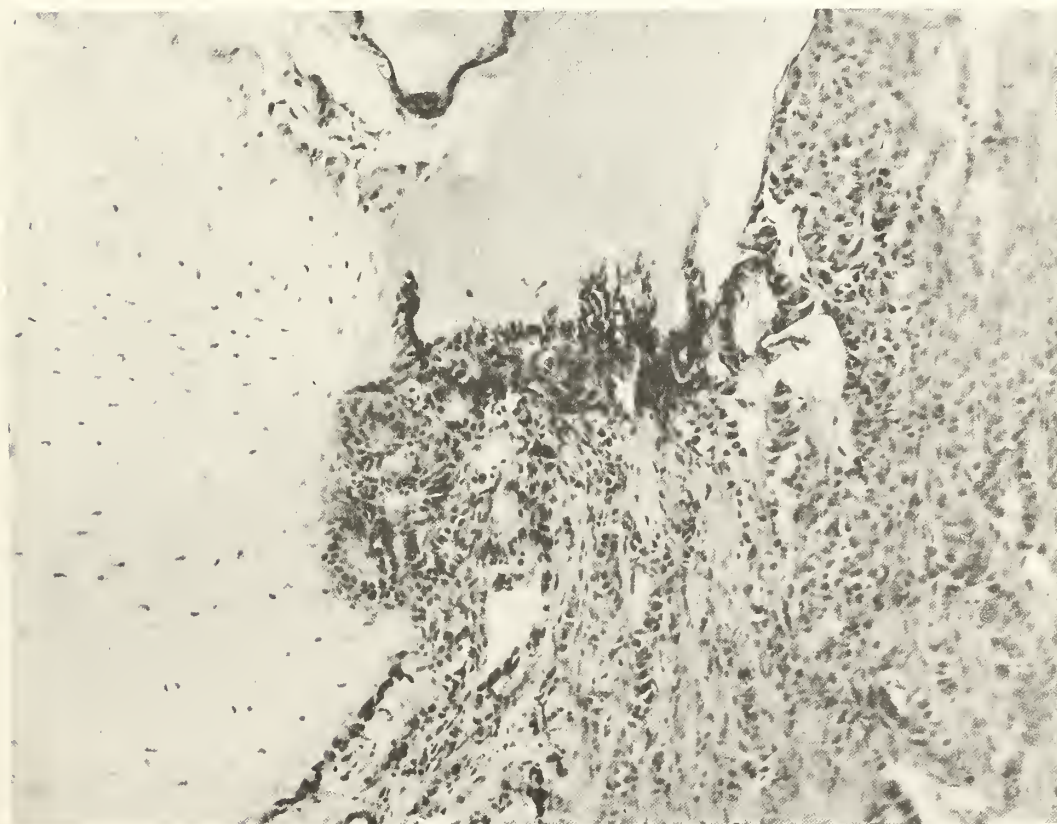


FIG. 49.—Section showing involvement and destruction of bone. X198.

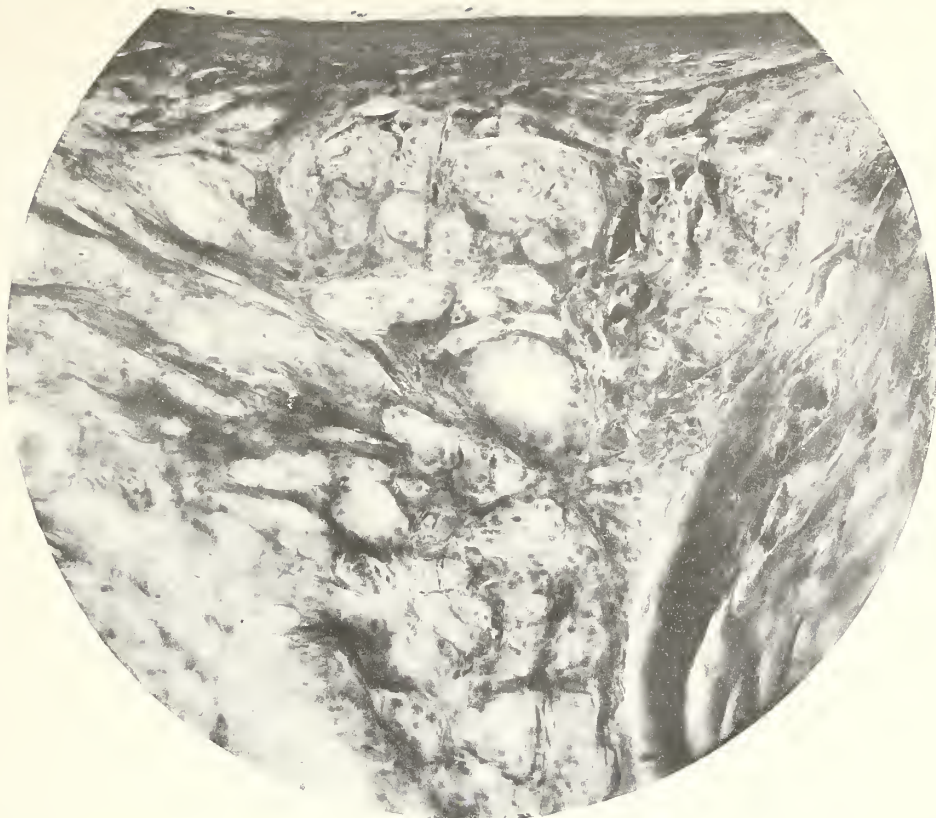


FIG. 50.—Section showing involvement of aortic wall. Tumor alveoli between elastic lamellæ of media. X260.

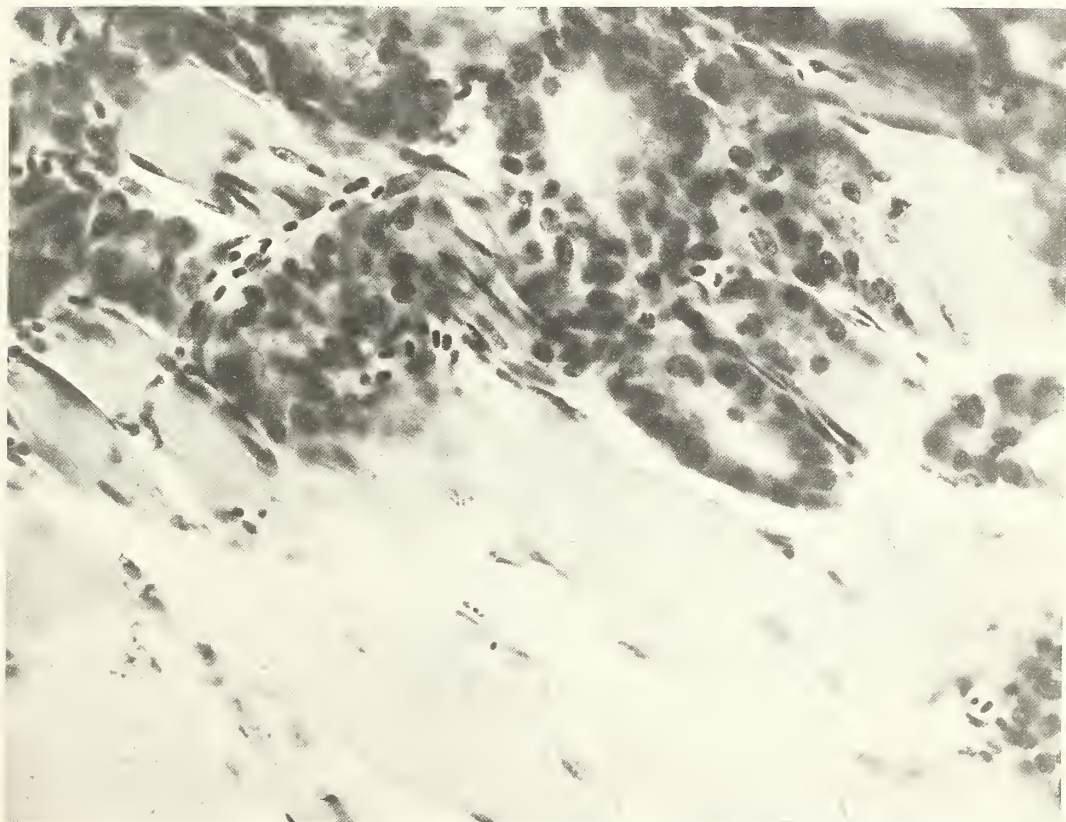


FIG. 51.—Section showing infiltration of individual muscle fibres. Cells within the sarcolemma. X500.

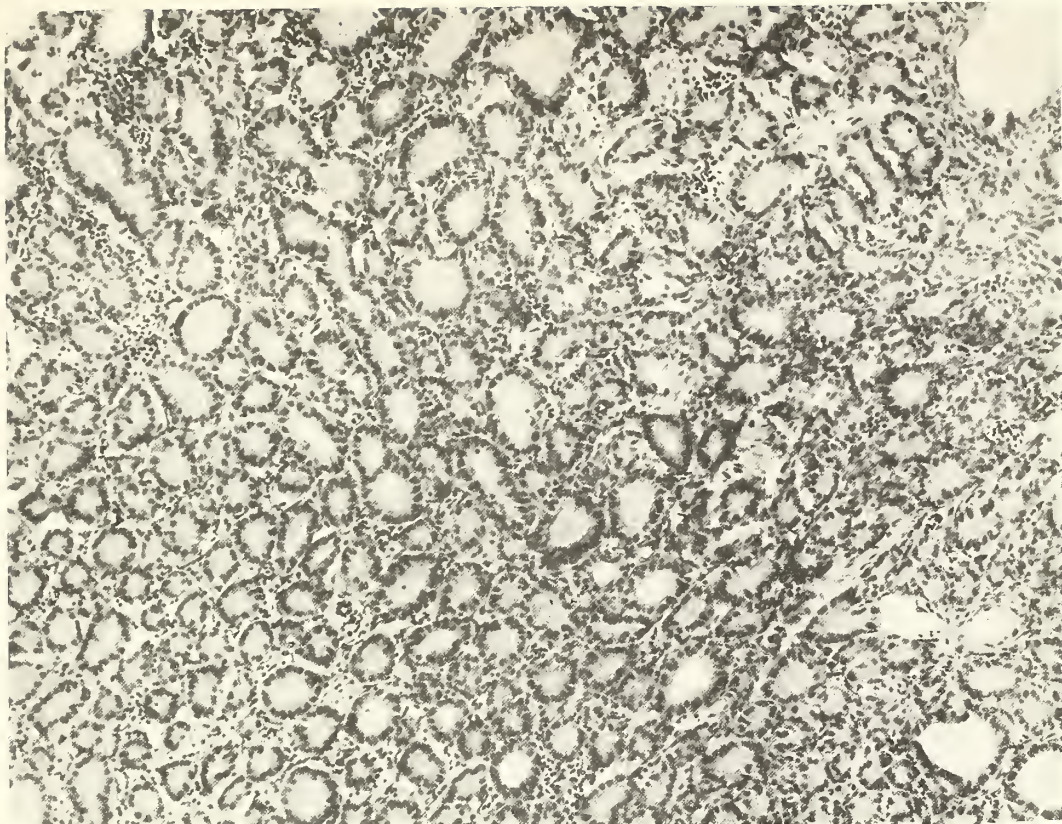


FIG. 52.—Primary tumor of thyroid region, Alveolar type. X136.

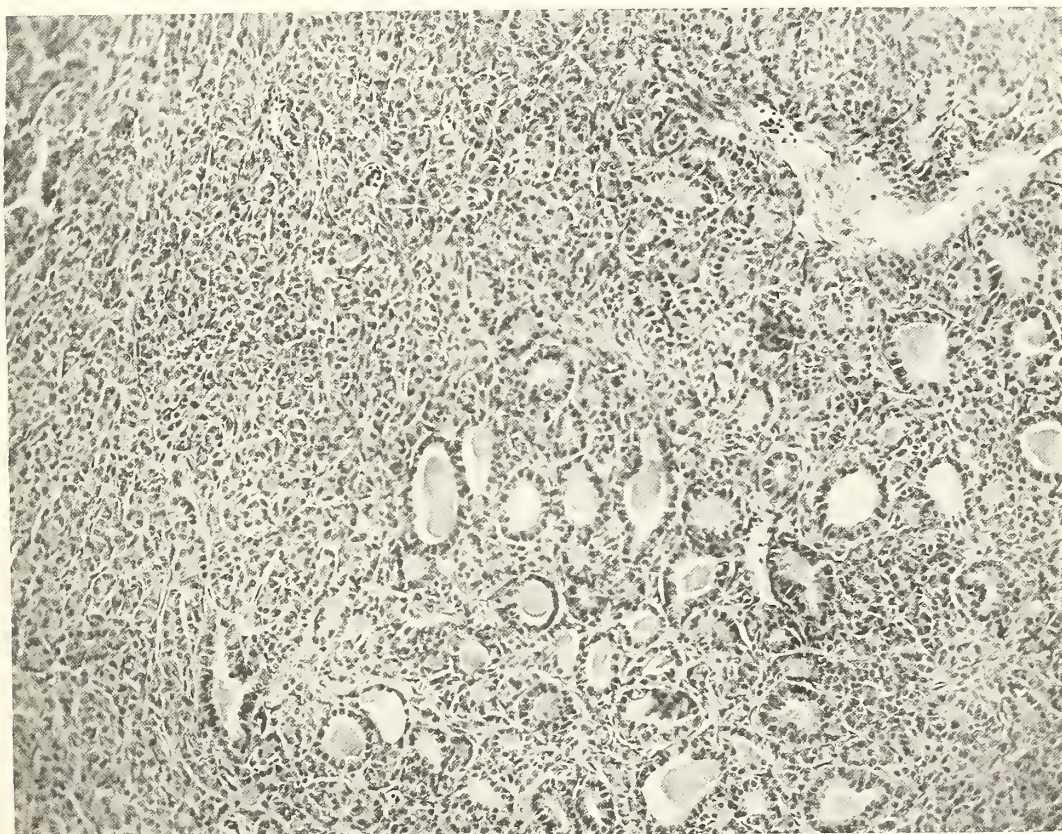


FIG. 53.—Section of metastasis on the tip of the jaw; from the primary tumor shown in figure 52. X136.

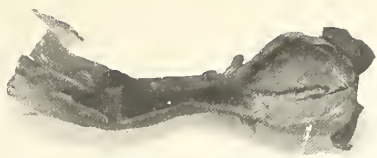


FIG. 54.—Photograph of metastatic tumor in the rectal wall.
Normal size.

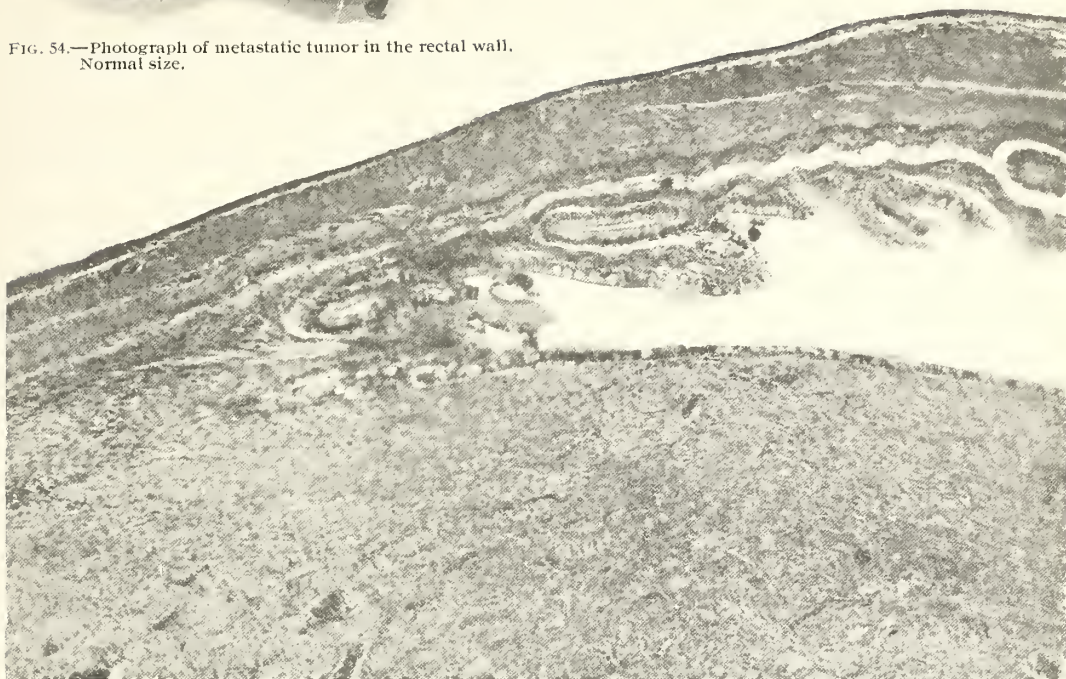


FIG. 55.—Microscopic section of rectal metastasis showing attachment to the intestinal wall; with extension of rectal mucosa over surface of tumor. X86.

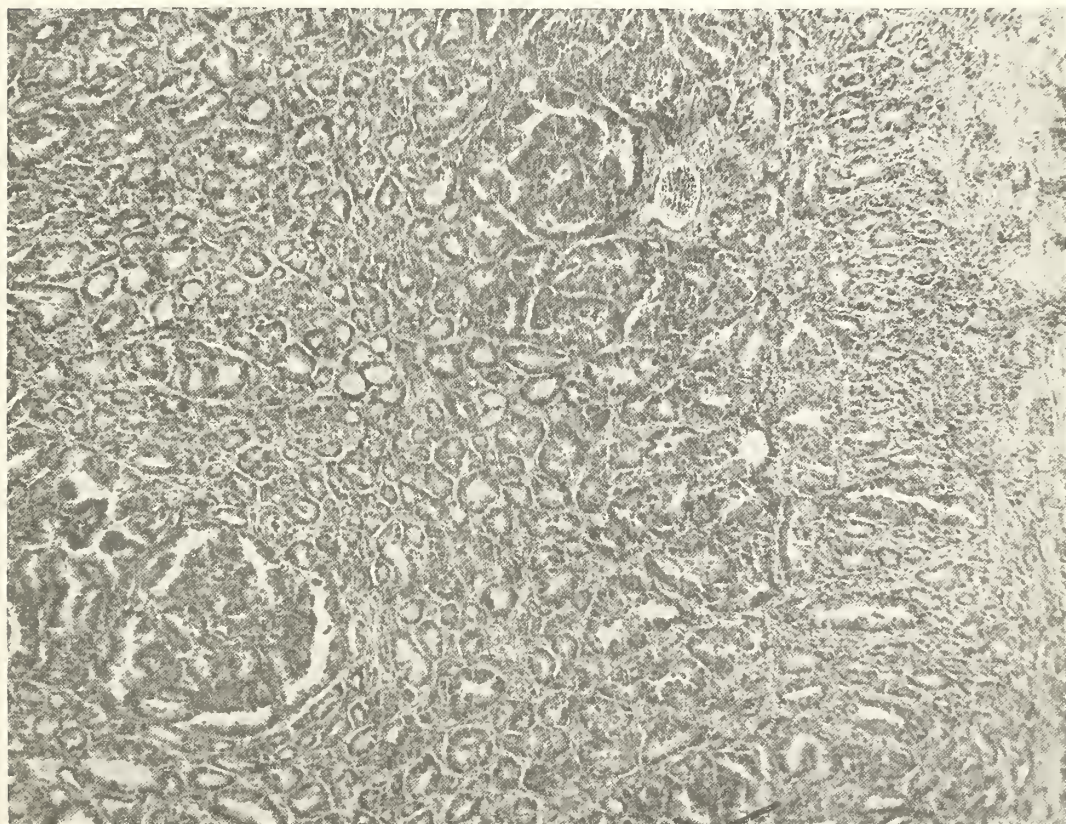


FIG. 56.—Section of rectal metastasis showing tendency to the formation of papillar nodules. X86.

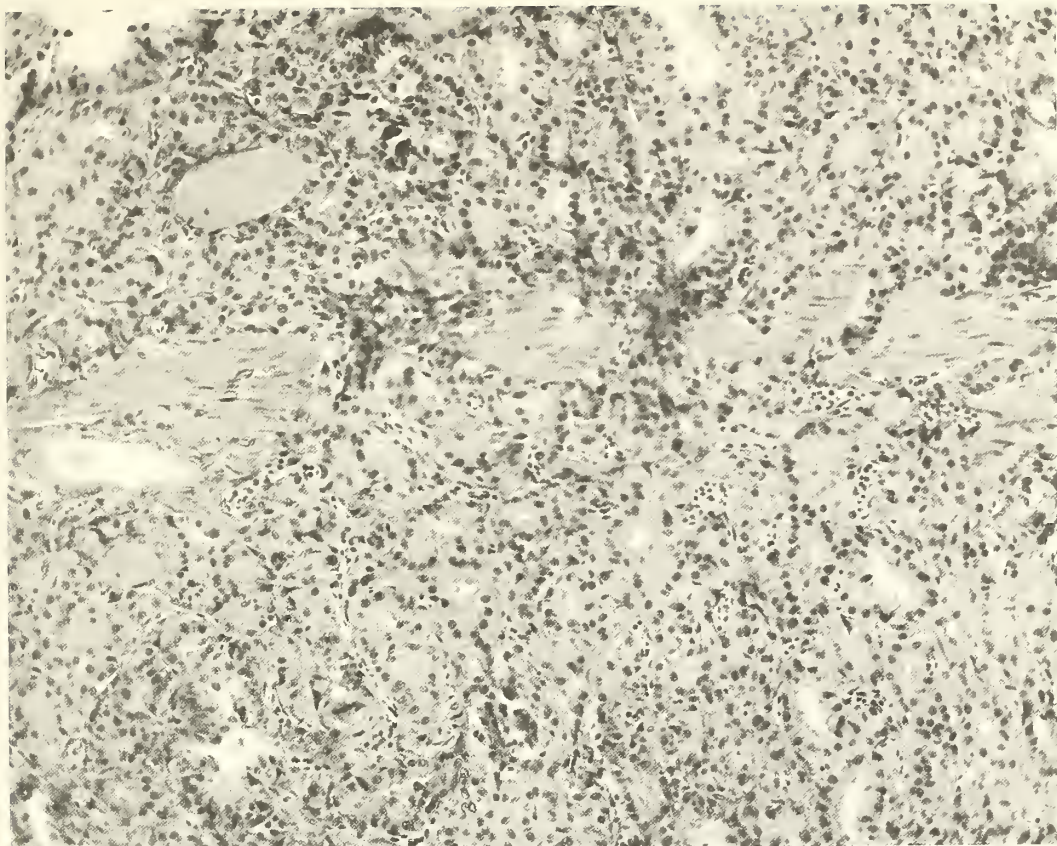


FIG. 57.—High power section of rectal metastasis showing infiltration of the muscularis mucosa. X160.



FIG. 58.—Section showing peculiar type of fish thyroid tumor which may be compared with plate 2, figure 6, of Langhans' article on malignant disease in the human thyroid. X160.

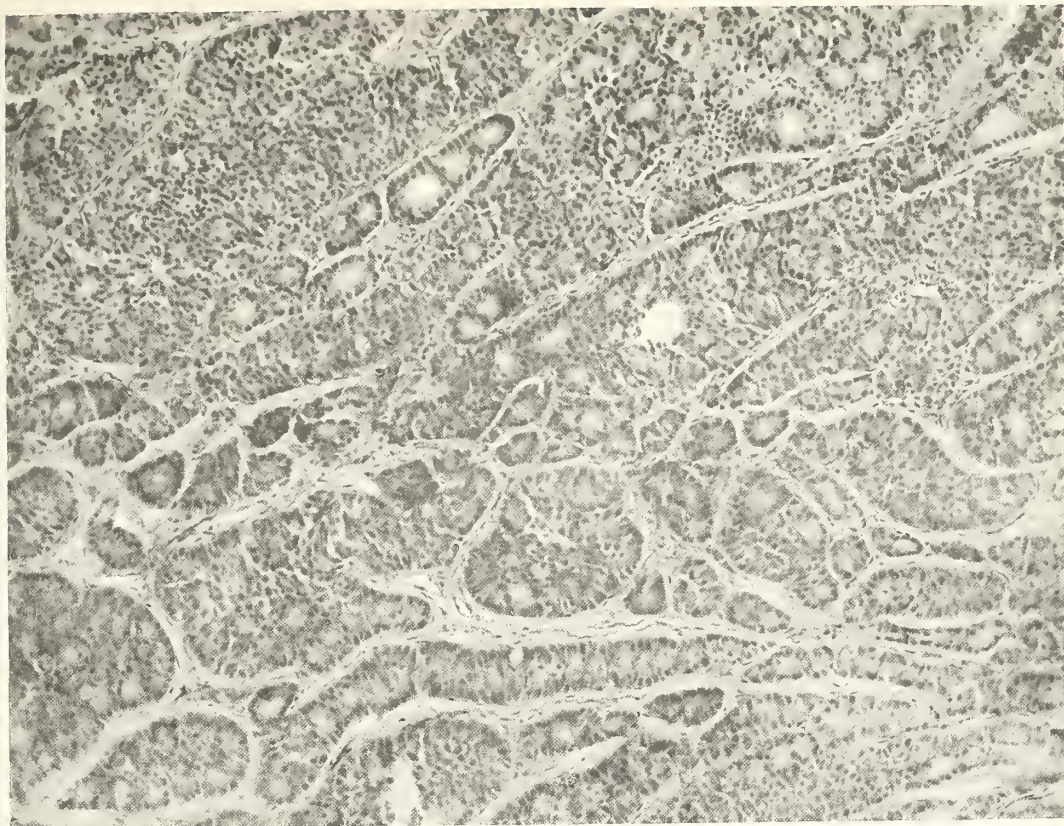


FIG. 59.—Section of fish thyroid tumor resembling the proliferating struma of Langhans as illustrated in plate 2, figure 12, of his article. X160.

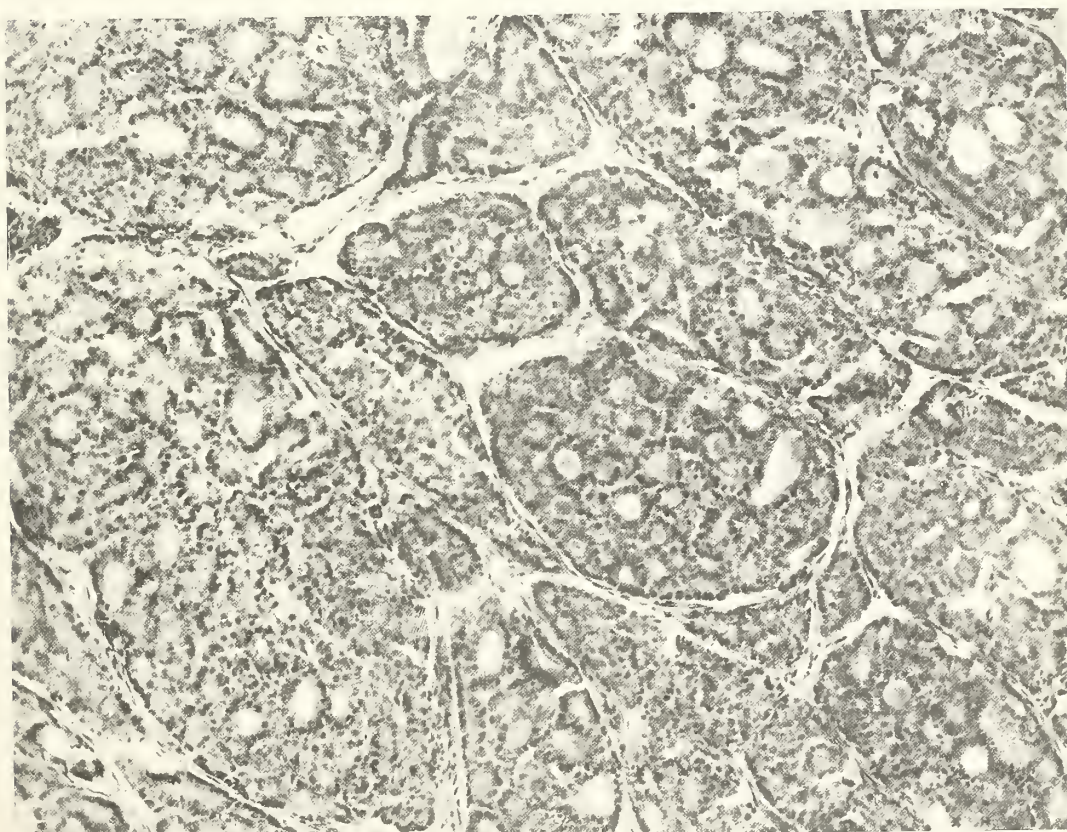


FIG. 60.—Section of proliferating struma in man; original case of Langhans to be compared with figure 58. X160.

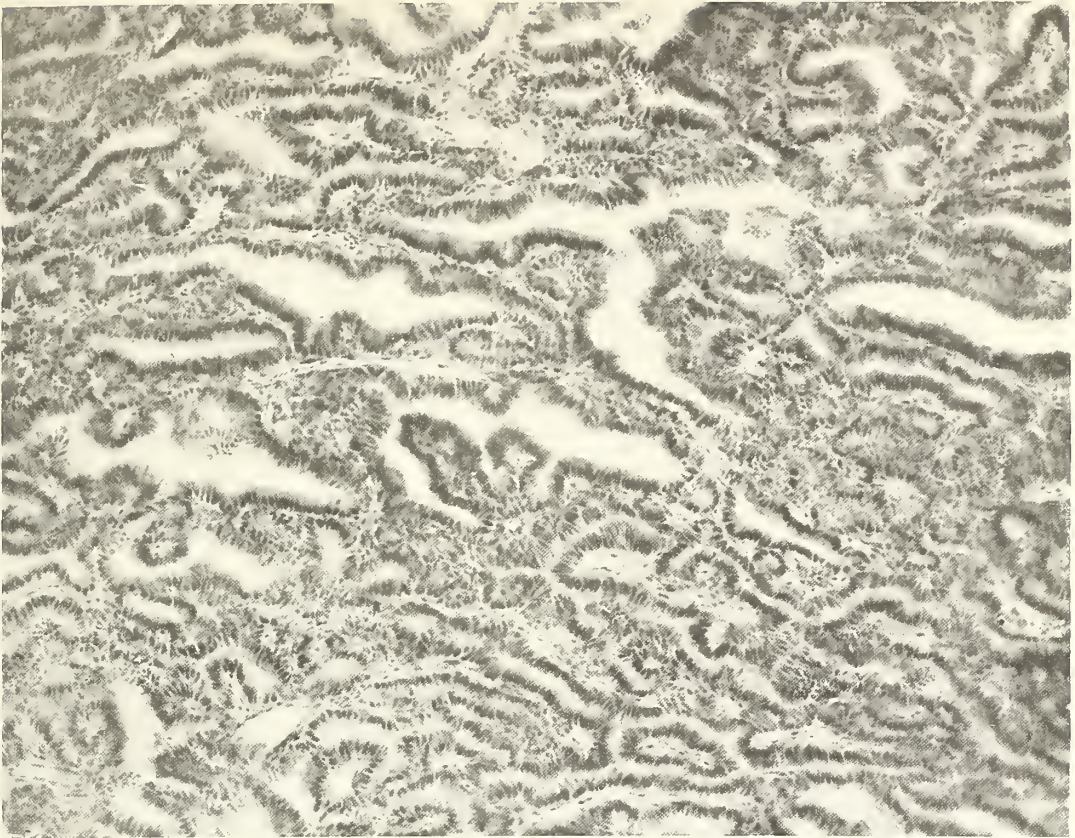


FIG. 61.—Papillar type in fish thyroid tumor resembling malignant papillar type in man, as illustrated in Langhans' article, plate 7, figure 32. X160.

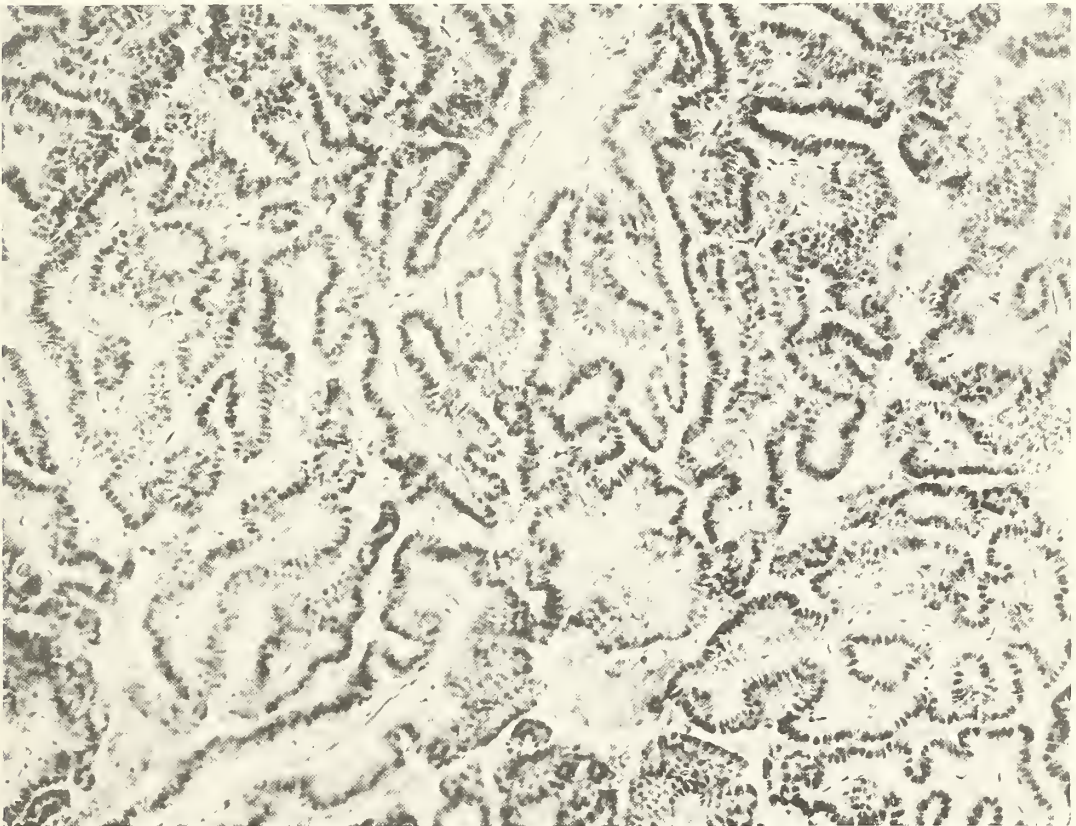


FIG. 62.—Section of malignant papillar type in man. Section of Langhans' original case; to be compared with figure 60. X160.

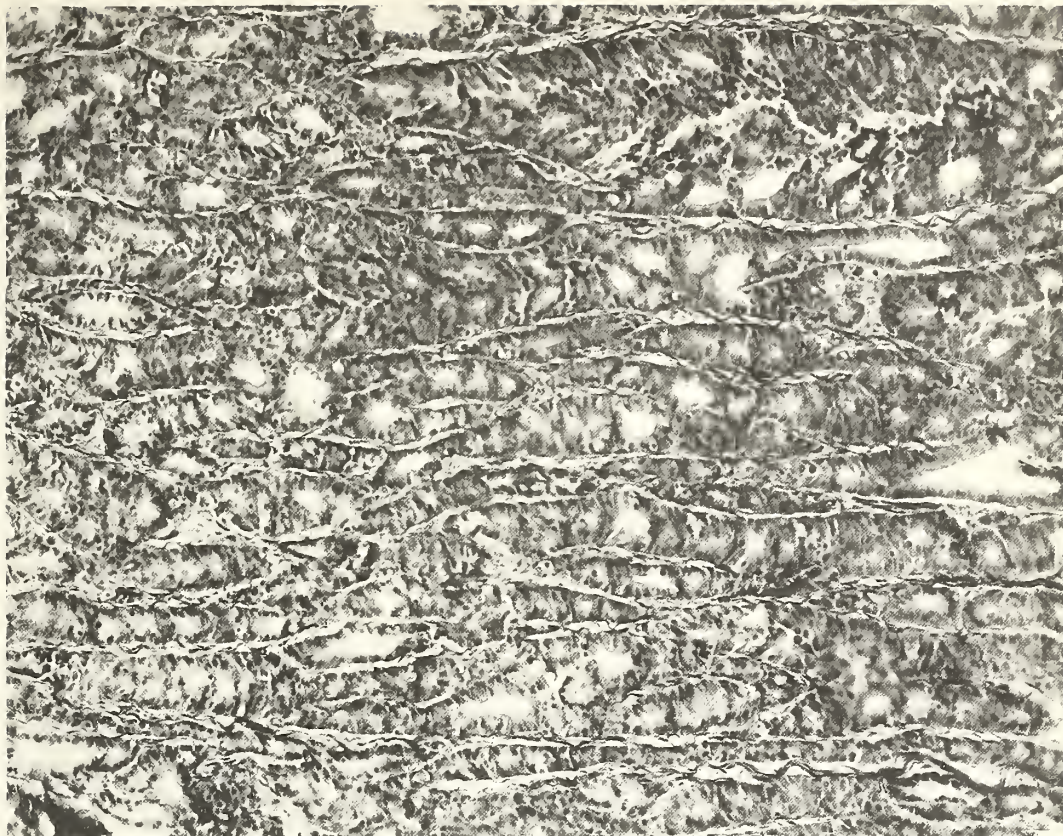


FIG. 63.—Fish thyroid tumor showing tubular type resembling the struma of Geisslar, as illustrated in plate 6, figure 27 of Laug hans' article. X160.

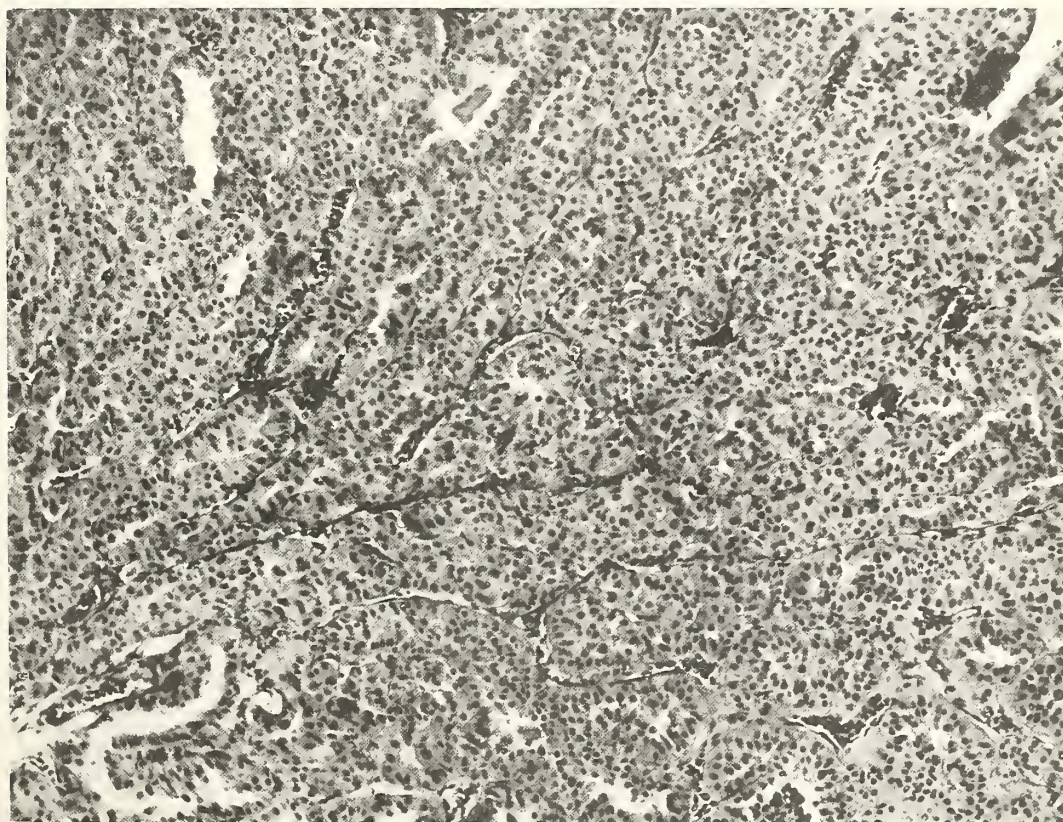


FIG. 64.—Section of fish thyroid tumor. Solid type. From five-months-old domesticated brook trout. (See fig. 72.) X160.

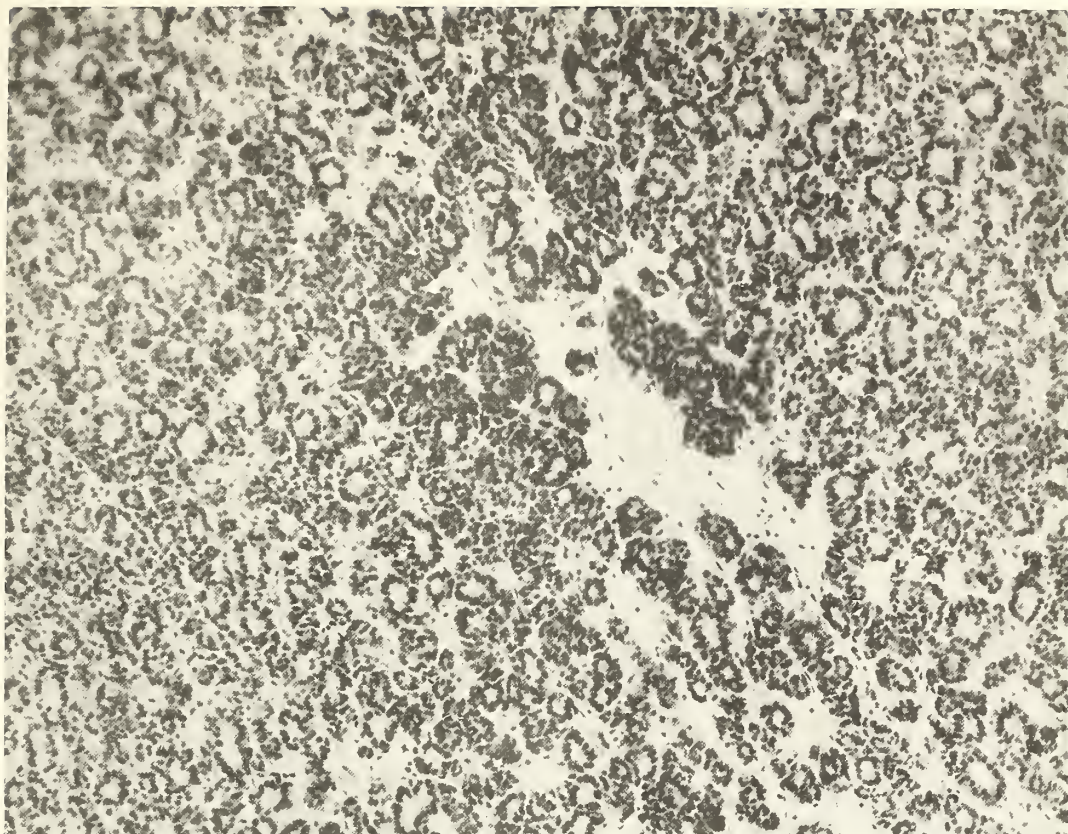


FIG. 65.—Section of fish tumor closely resembling the so-called struma nodosa, with "Wachstum centrum" of Aschoff. X160.

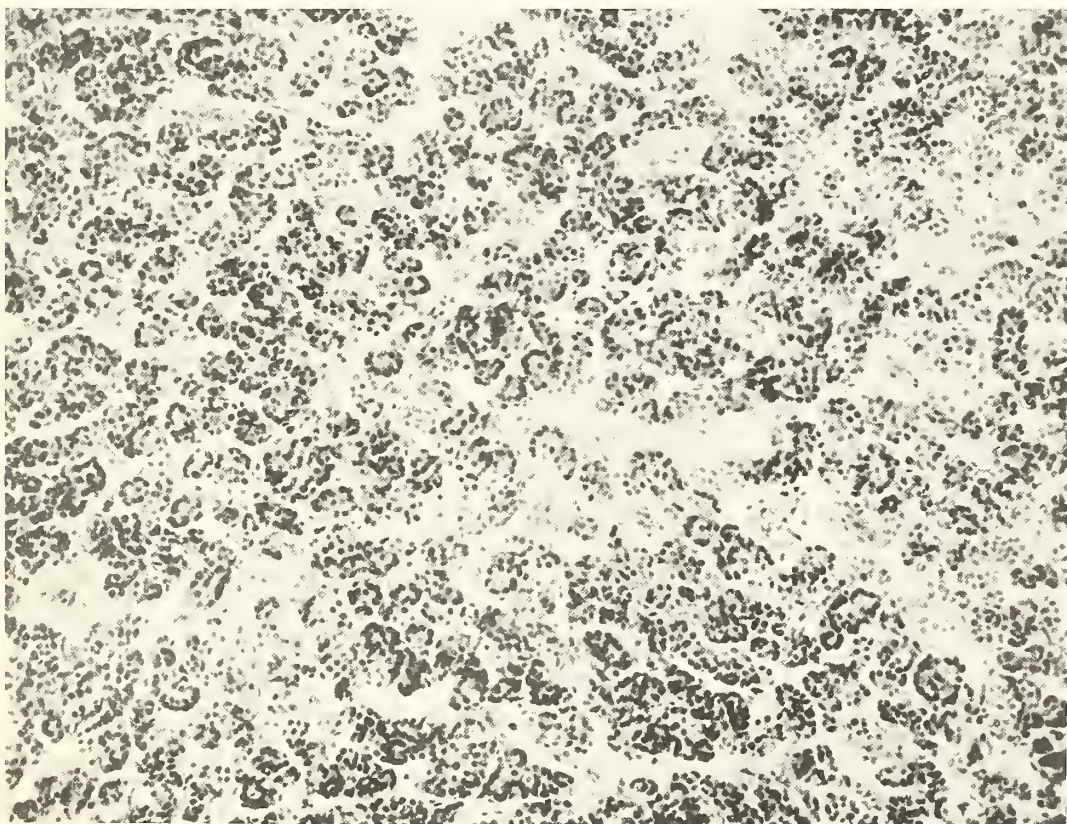


FIG. 66.—Section of struma nodosa from a human thyroid gland; to be compared with figure 64. X160.

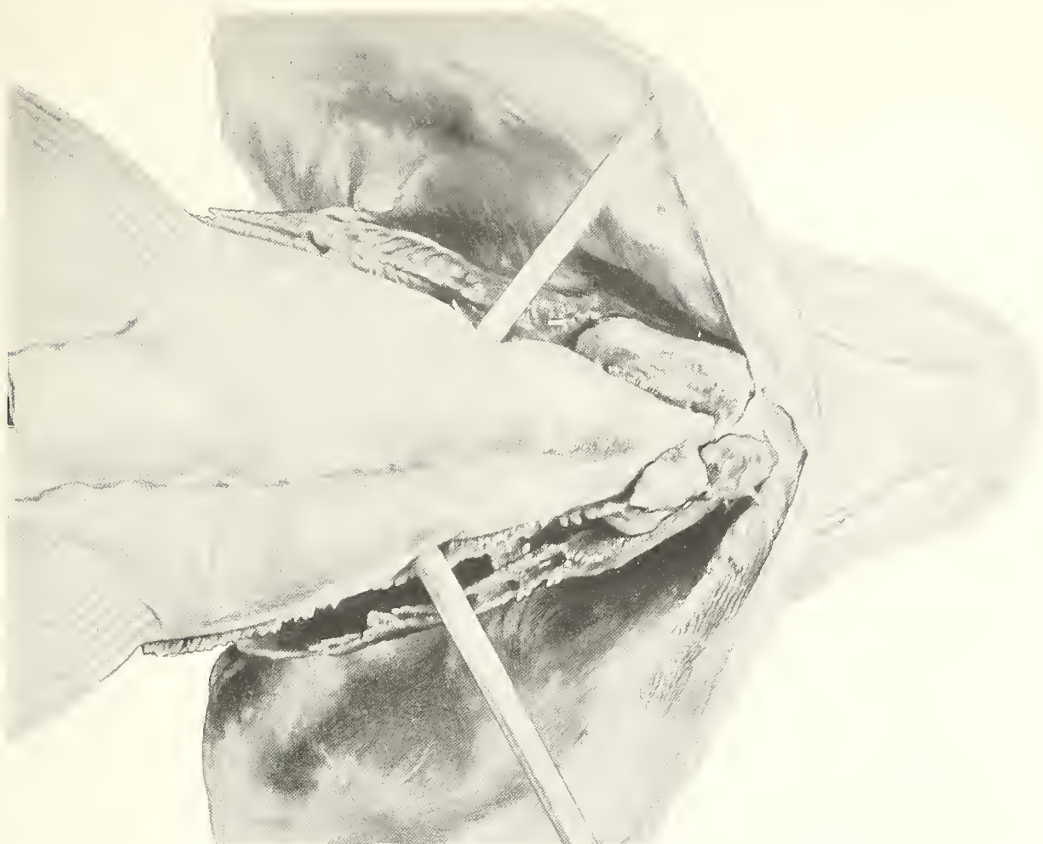


FIG. 67.—Infiltrating thyroid tumors in the gill region of a wild white fish (*Coregonus clupeaformis*.)

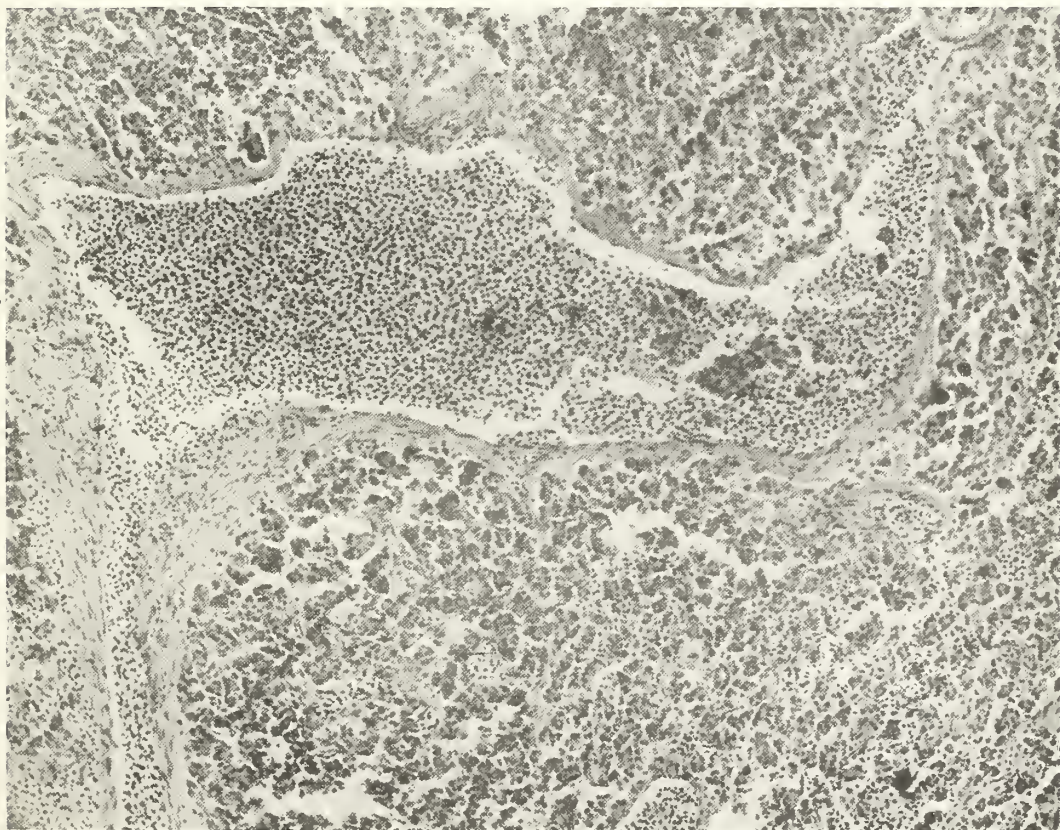


FIG. 68.—Microscopic section of the tumor shown in figure 66. Infiltration of wall of vein. Cell nests in lumen, X136.



FIG. 69.—Photograph showing tumor in a wild brook trout (*Salvelinus fontinalis*.)



FIG. 70.—Low power photomicrograph of the tumor of figure 68. Note the large nodule within the tumor mass. $\times 9\frac{1}{2}$.

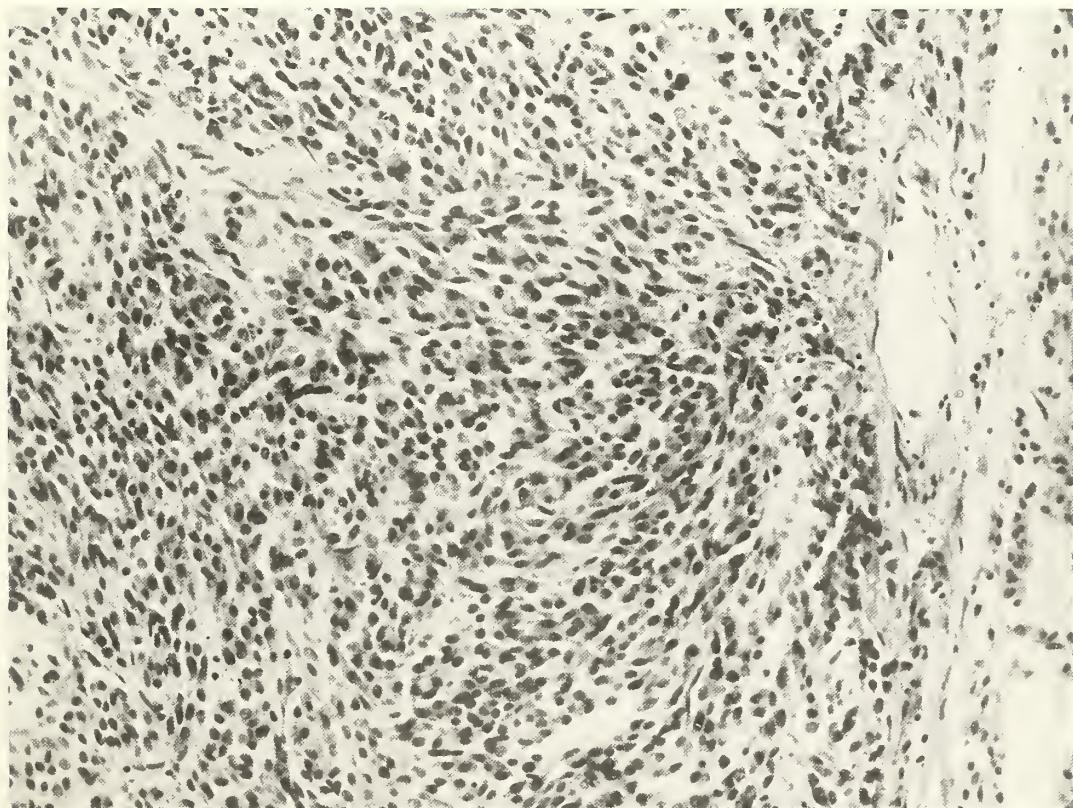


FIG. 71.—High power photomicrograph of the tumor in figure 68. Note the spindle cell character of the tumor resembling spindle cell sarcoma. $\times 280$.



FIG. 72.—Massive thyroid tumors in wild *Salmo sebago* 4 years old, caught in Sebago Lake, Maine. Largest fish observed with tumors. Natural size.

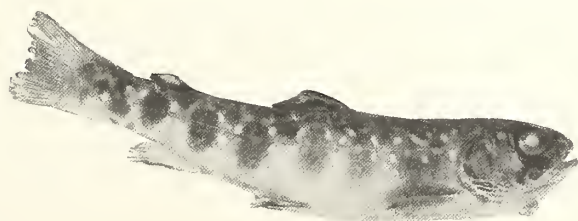


FIG. 73.—Smallest tumor fish, domesticated brook trout 5 months old. Natural size.



FIG. 74.—Photograph of longitudinal section of lower jaw of landlocked salmon; illustrated by figure 72.

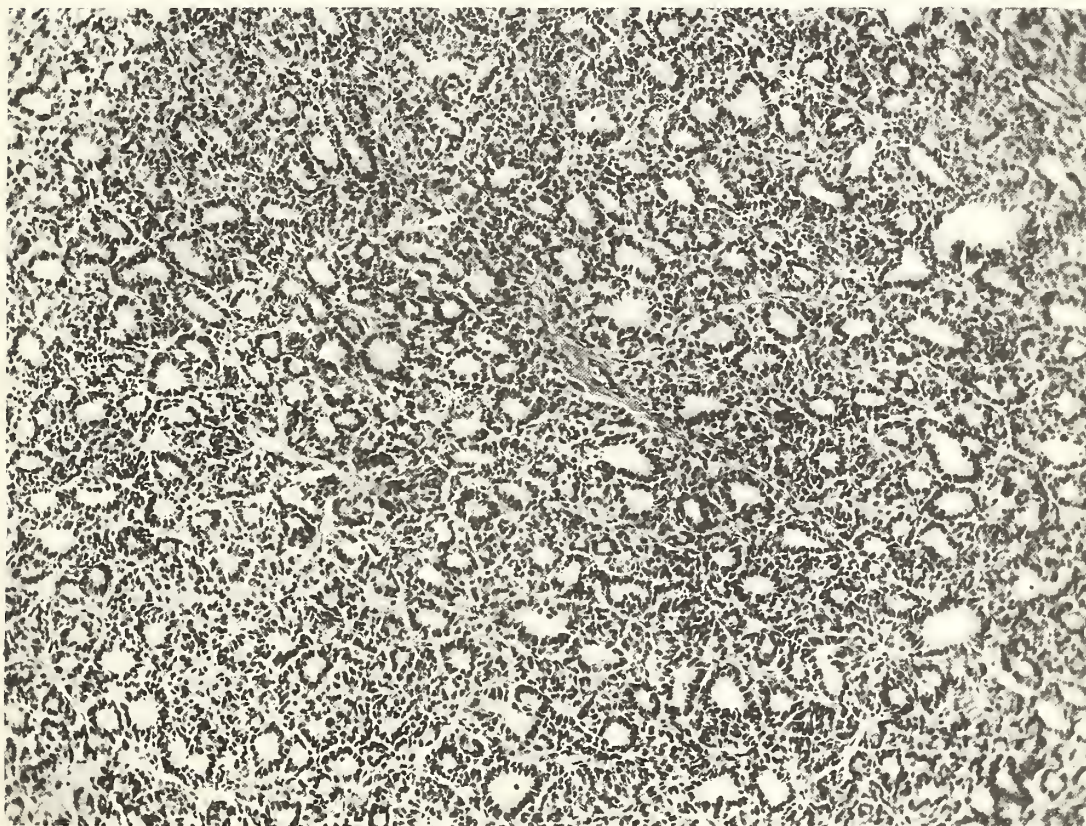
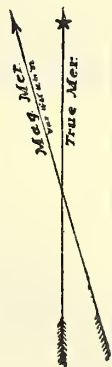


FIG. 75.—Section showing alveolar type of tumor. Wild landlocked salmon. Illustrated by figure 71. X160.

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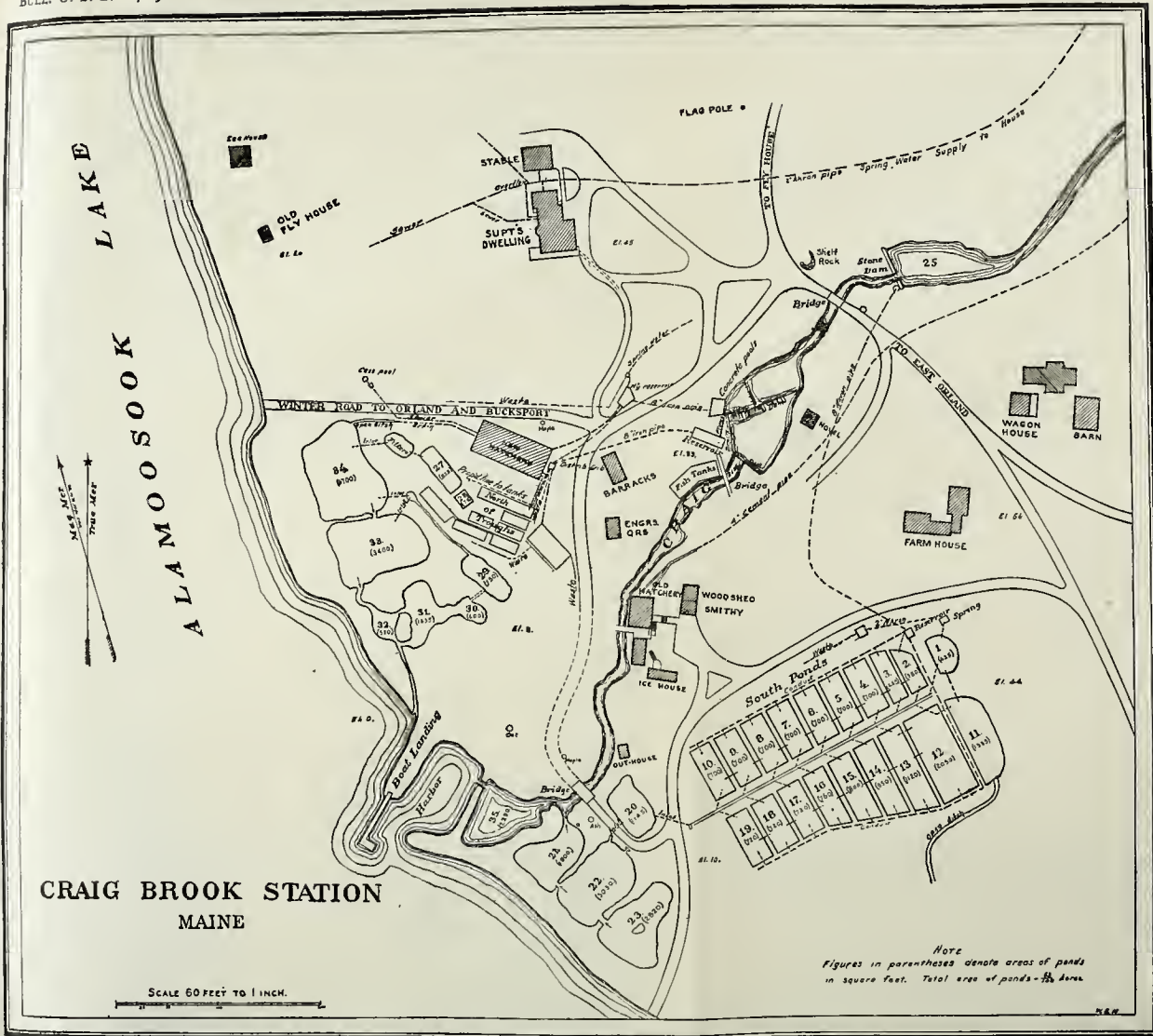


FIG. 77.—Plan of U. S. Fisheries Station (Craig Brook) near East Orland, Me.

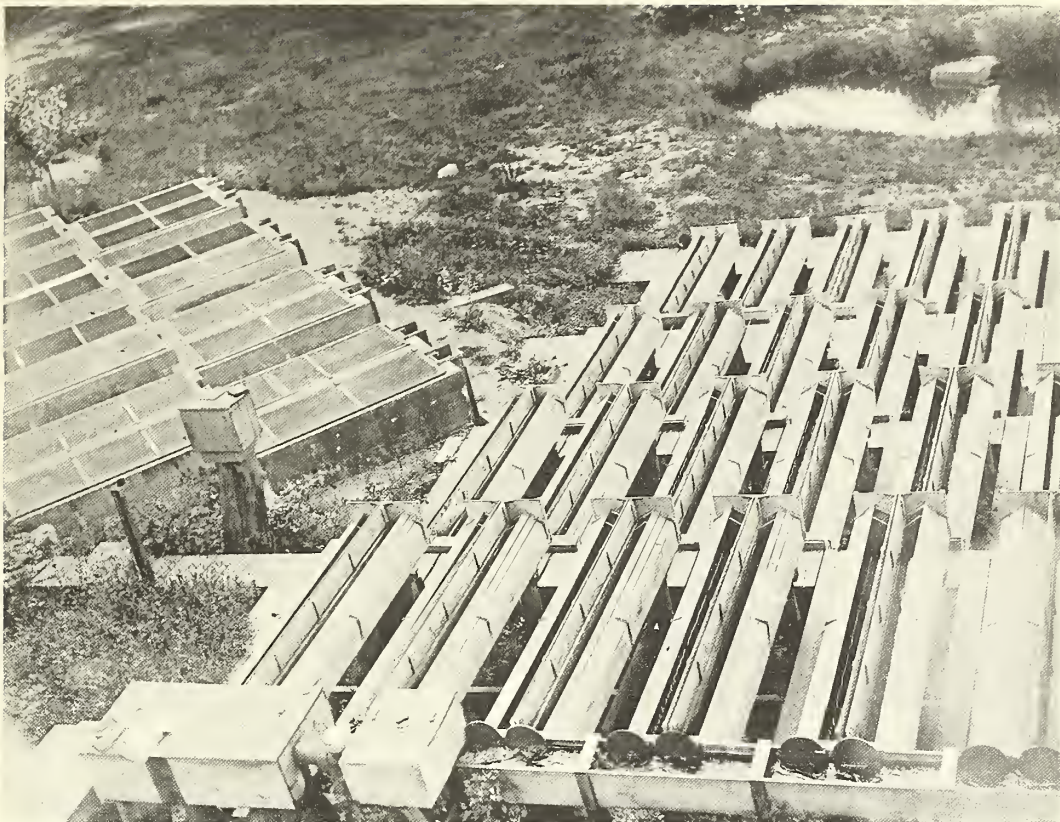


FIG. 79.—Photograph of outdoor troughs at Craig Brook. On the right, wooden troughs; on the left, cement tanks.



FIG. 80.—Photograph showing dirt pond No. 11 at Craig Brook.



FIG. 82.—Large pond, spring water supply at Pleasant Valley station.

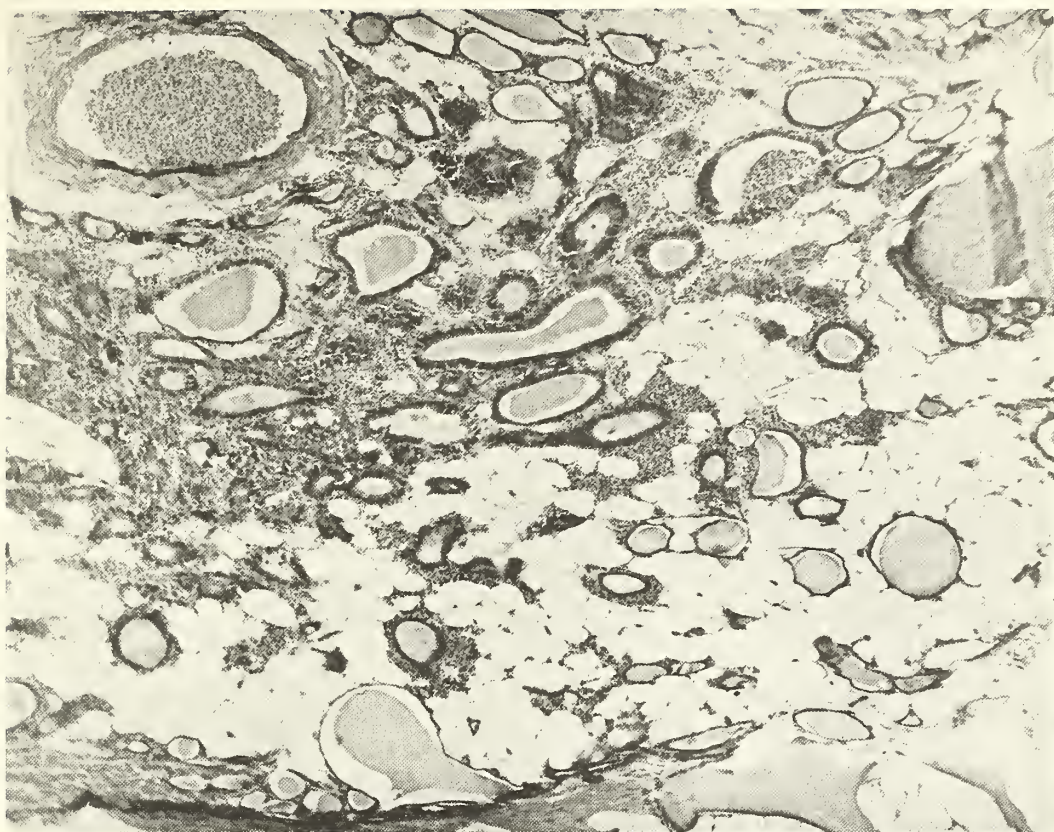


FIG. 84.—Section of wild Wisconsin brook trout. Raw liver feeding 12 months. Focal development carcinoma of the thyroid. Small group of follicles with columnar epithelium. Reduced colloid. Hyperaemia about follicles. At periphery normal unaltered thyroid follicles. X86.

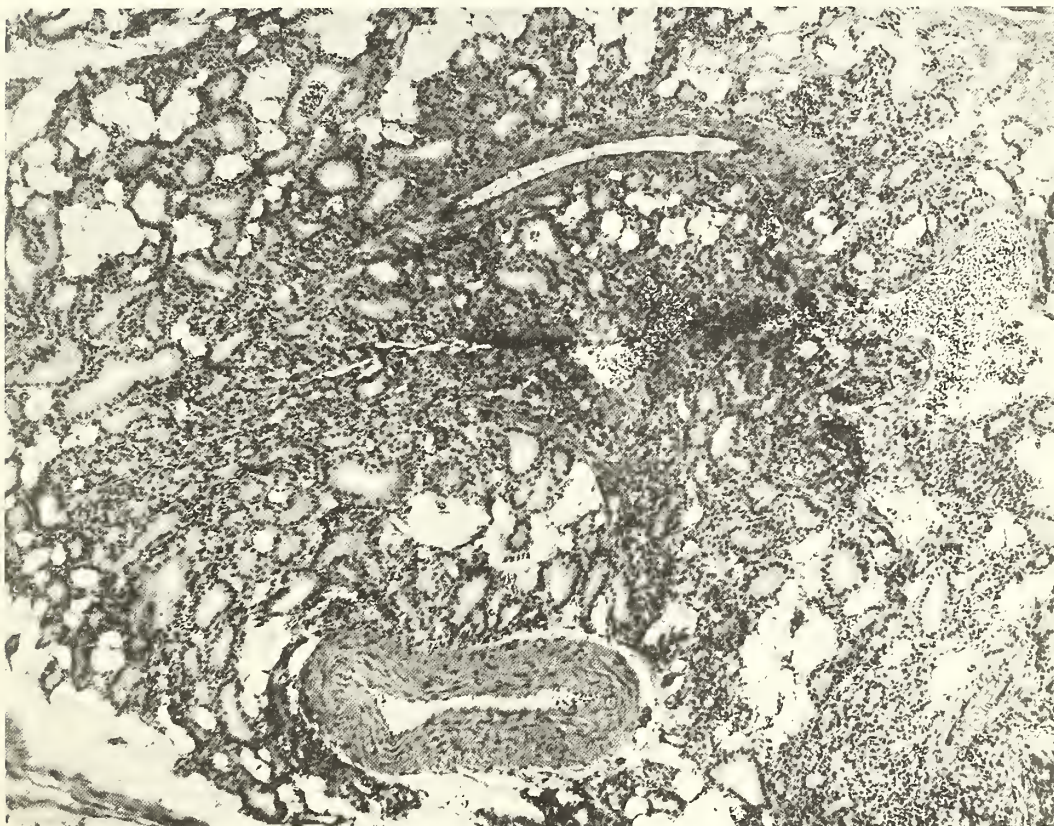


FIG. 85.—Wild Wisconsin brook trout. Raw heart feeding 12 months. Beginning carcinoma of the thyroid. X86.



FIG. 86.—Section of wild Wisconsin brook trout from same experiment. Natural food 12 months. Normal thyroid. X86.

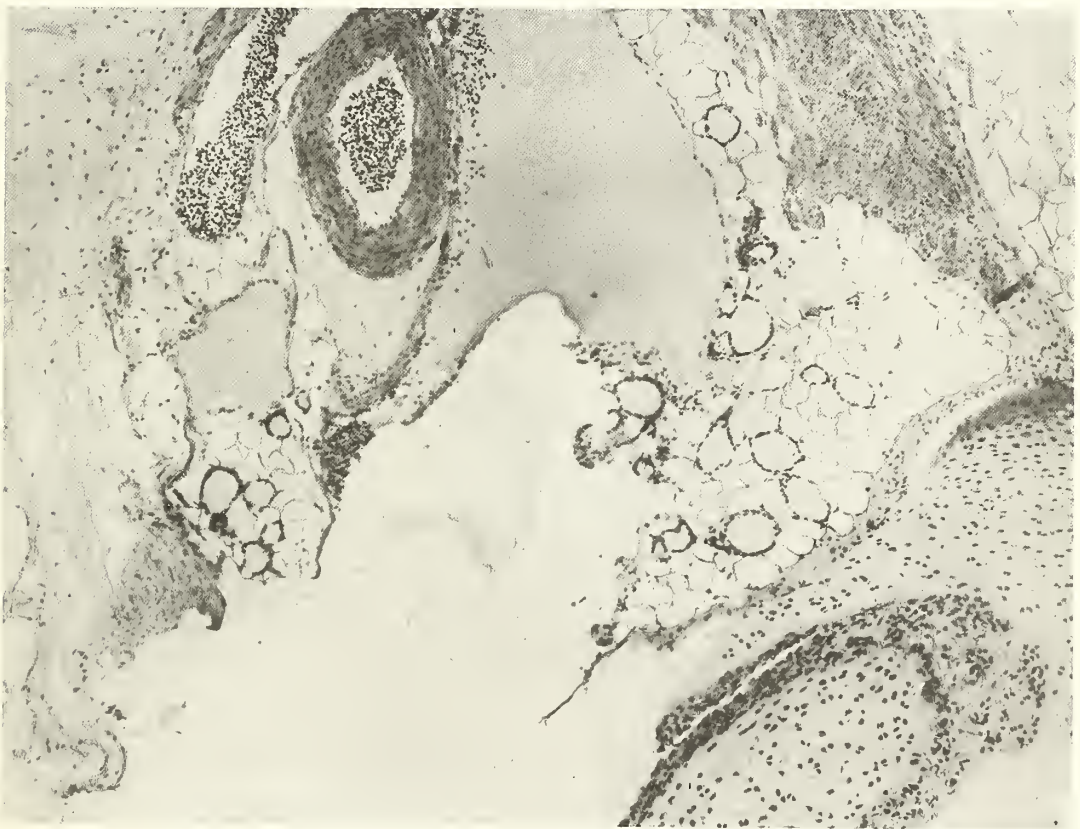


FIG. 87.—Section of wild Wisconsin brook trout. Cooked liver feeding 12 months. Normal thyroid. X86.



FIG. 88.—Wild Wisconsin brook trout. Fed marine fish 12 months. Normal thyroid. X86.

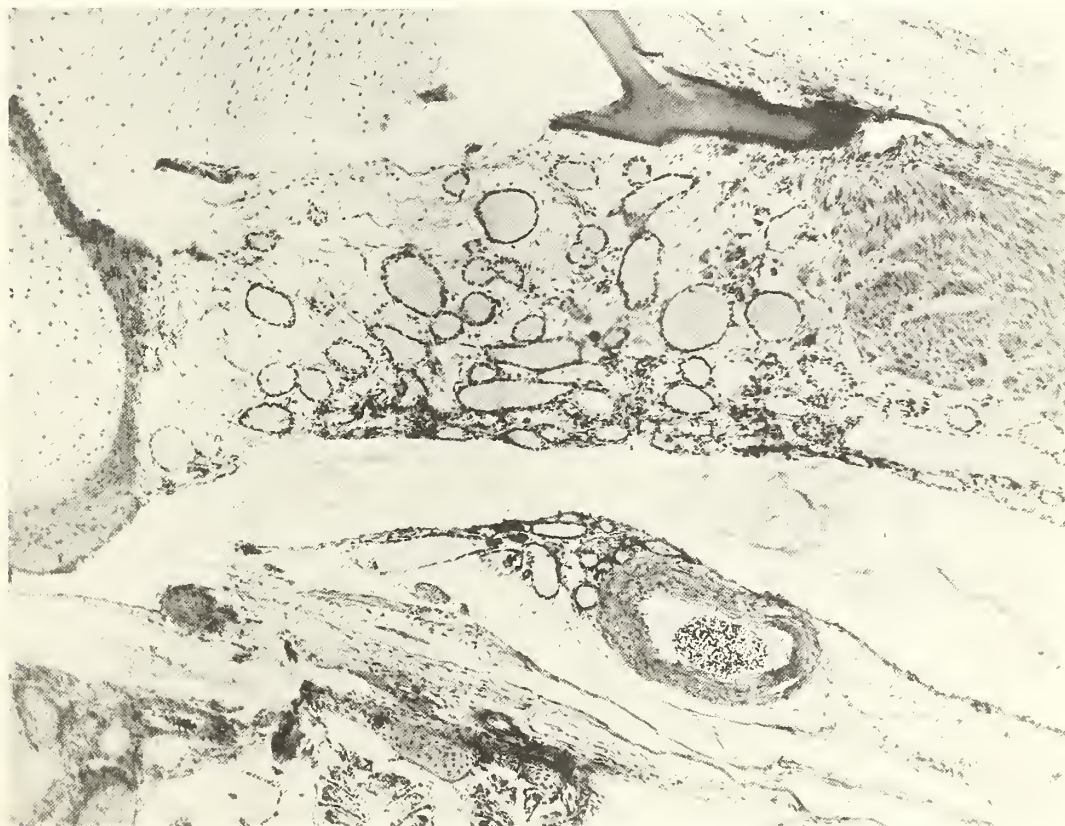


FIG. 89.—Wild Wisconsin brook trout. Vegetable food 12 months. Normal thyroid. X86.



FIG. 90.— Low power section at median line through thyroid region of wild Wisconsin brook trout, showing well-developed carcinoma of the thyroid infiltrating surrounding structures, bone and cartilage. After 18 months raw liver feeding at Craig Brook. Experimental induction of carcinoma of the thyroid. X13.

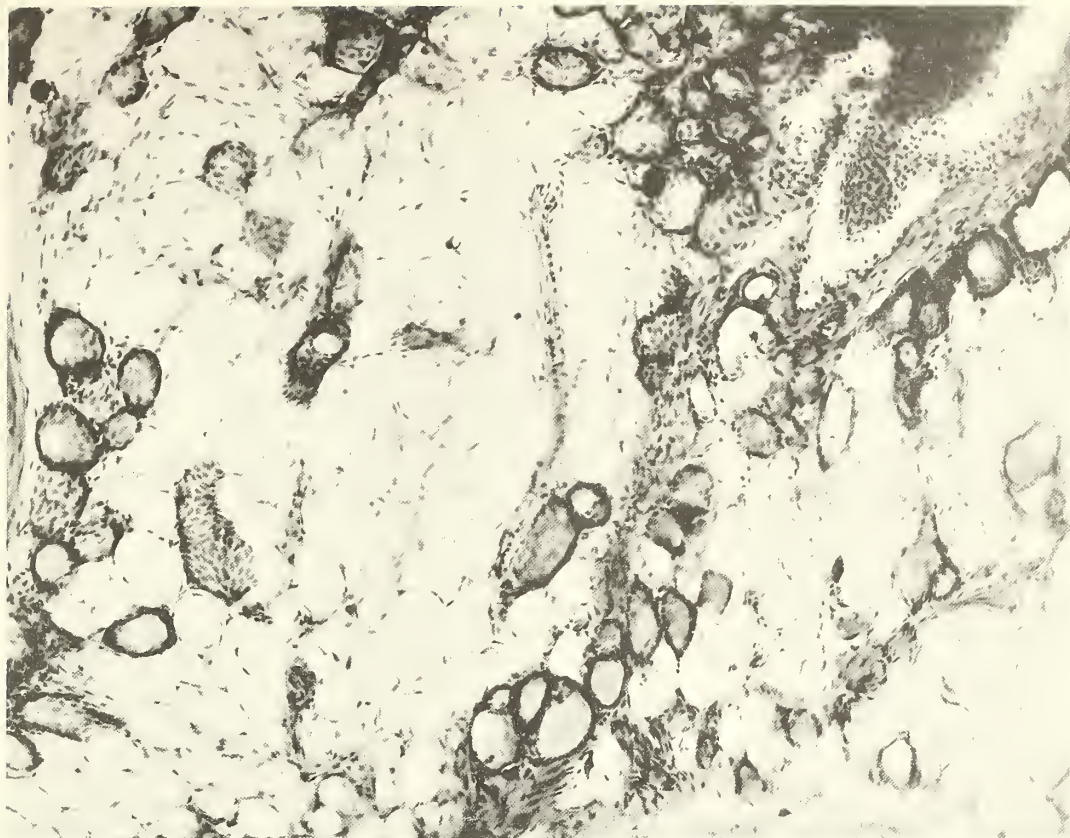


FIG. 91.—Section of thyroid showing spontaneous recovery from carcinoma of the thyroid. Early stage. Wild Wisconsin brook trout. Fish No. 2099 A. X86.

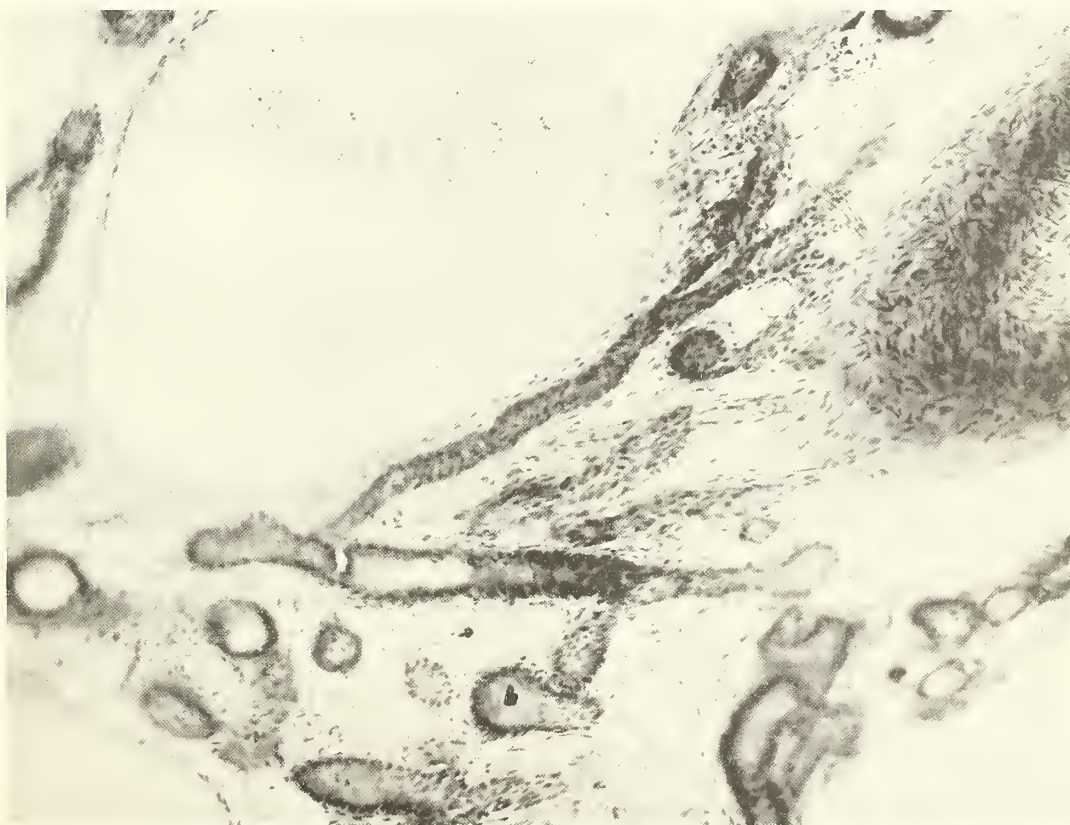


FIG. 92.—Section showing spontaneous recovery from experimentally induced carcinoma of the thyroid in wild Wisconsin brook trout. Fish No. 2099 B. X86.

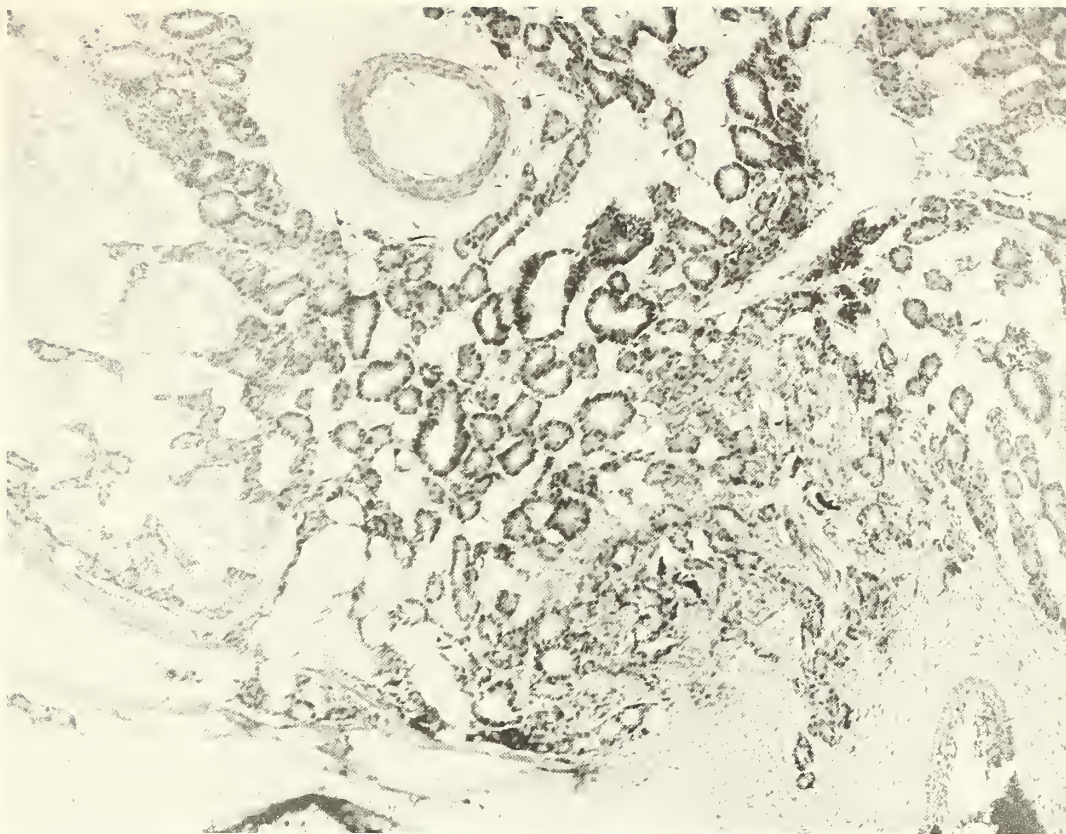


FIG. 93.—Section thyroid region domesticated yearling, Cold Spring Harbor hatchery, kept in old troughs. Raw liver and heart feeding. Well developed hyperplasia. X86.

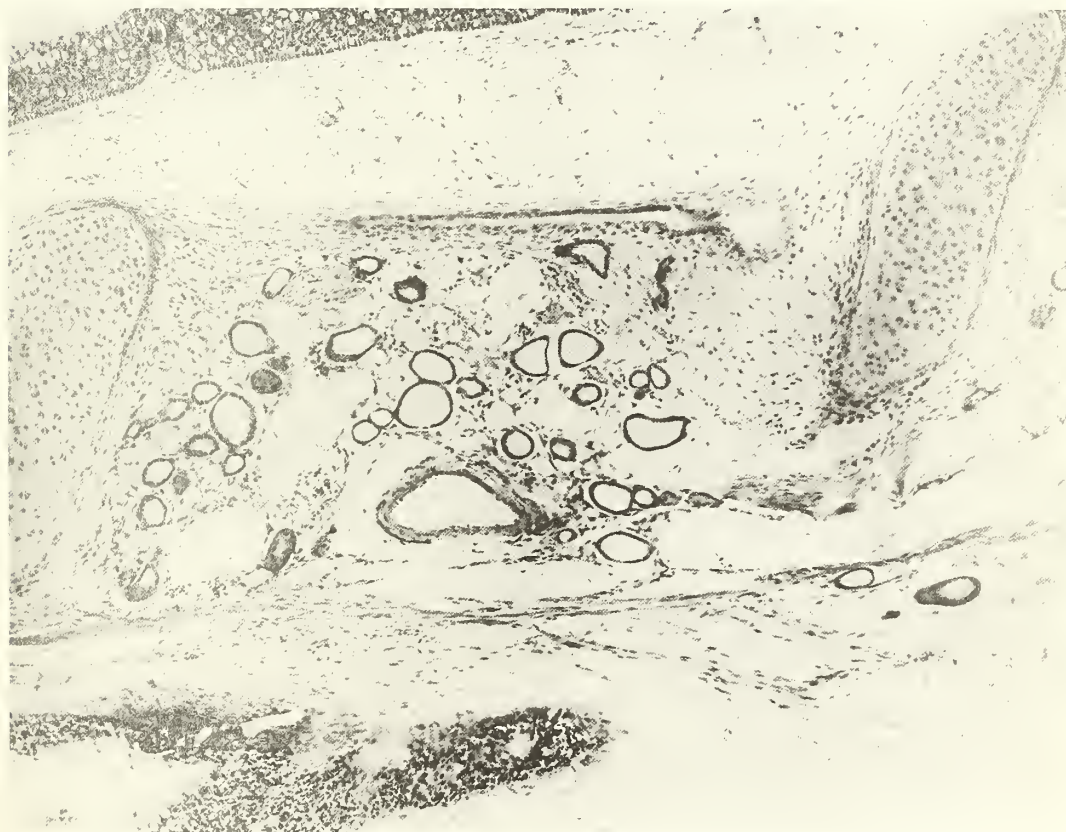


FIG. 94.—Yearling domesticated brook trout, Cold Spring Harbor hatchery. Same lot of fish as figure 93. Kept in water of Church Spring. Raw liver and heart feeding. Normal thyroid. X86.



FIG. 96.—Marked hyperplasia domesticated brook trout used as control for figure 97. Fish 1040, table ix. X86.

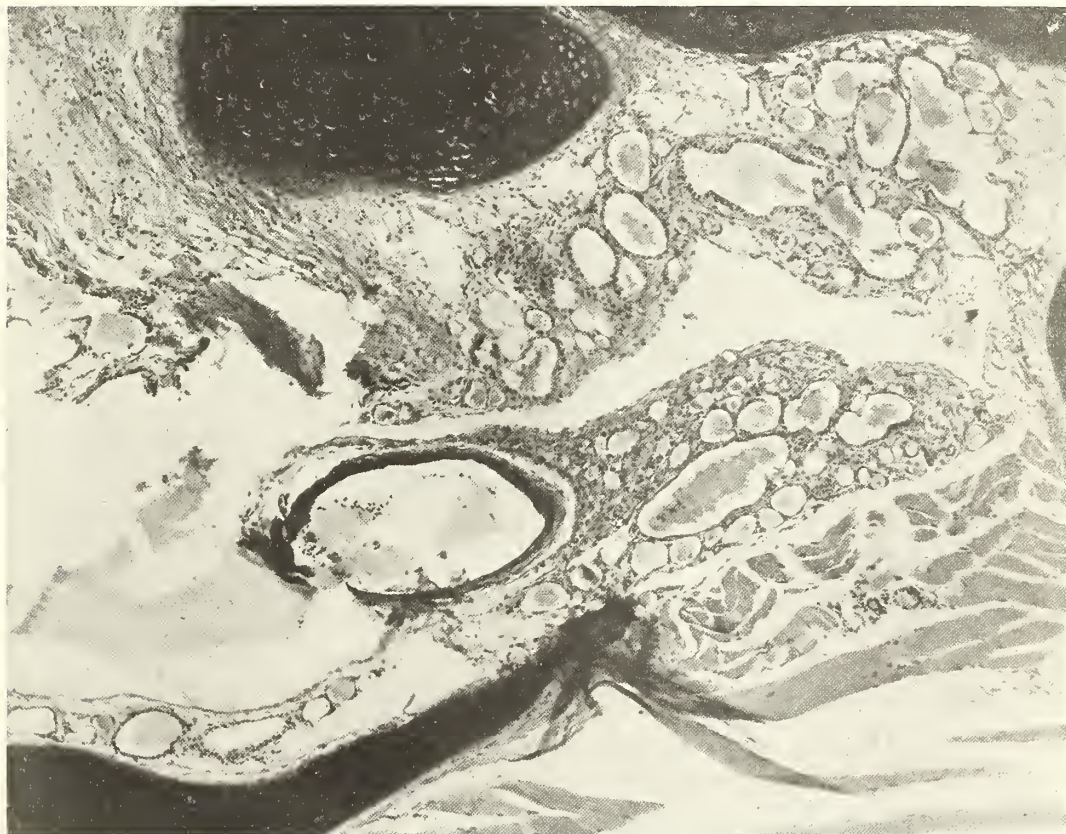


FIG. 97.—Fish from same lot treated by adding in continuous concentration potassium iodide in the water 1:5,000,000. Marked regression of hyperplasia at the end of 13 days. Fish 1039, table ix. X86.

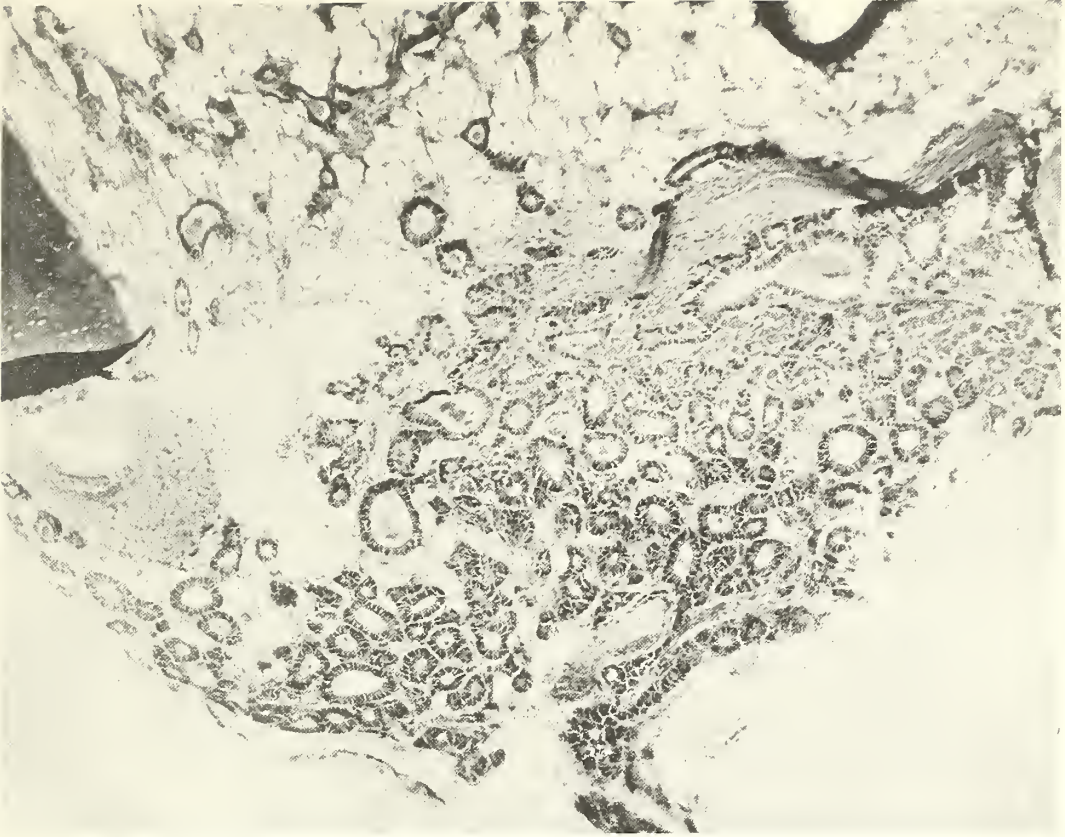


FIG. 98.—Marked hyperplasia domesticated brook trout used as control for figure 99. Fish 1070, table IX. X86.

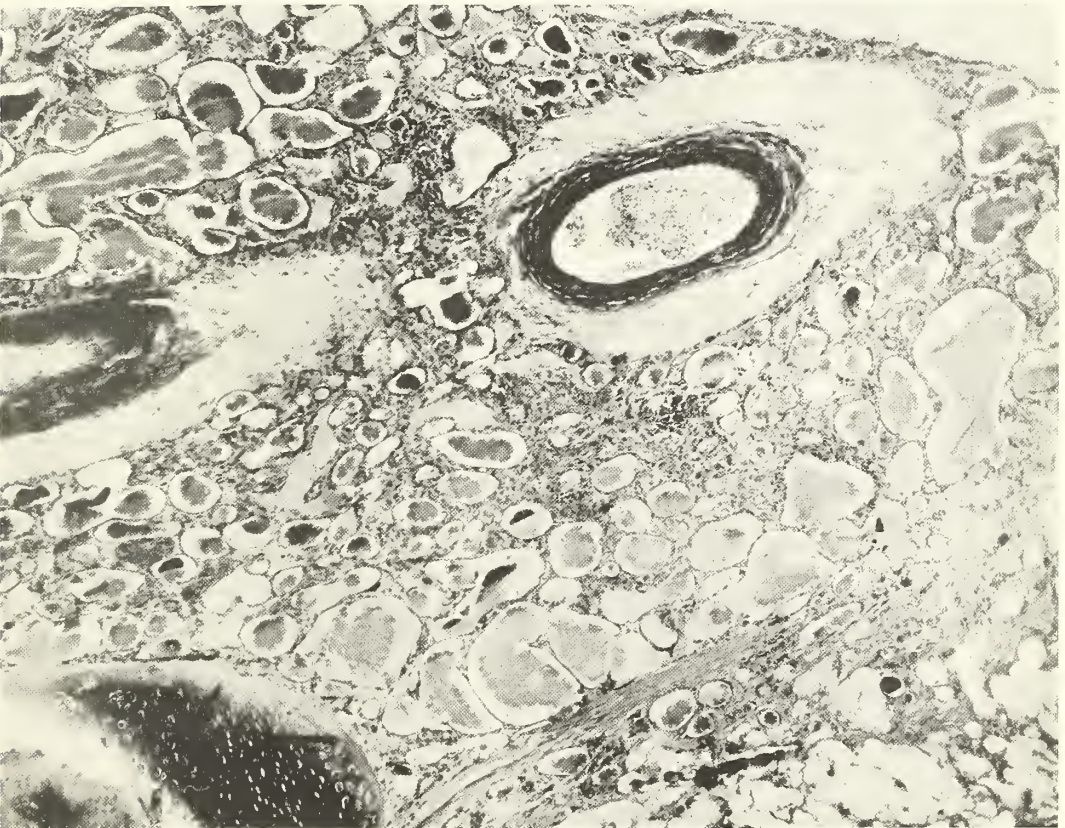


FIG. 99.—Fish from same lot treated by adding in continuous concentration potassium iodide in the water 1 : 5,000,000. Marked regression of hyperplasia at the end of 27 days. Fish 1069, table IX. X86.

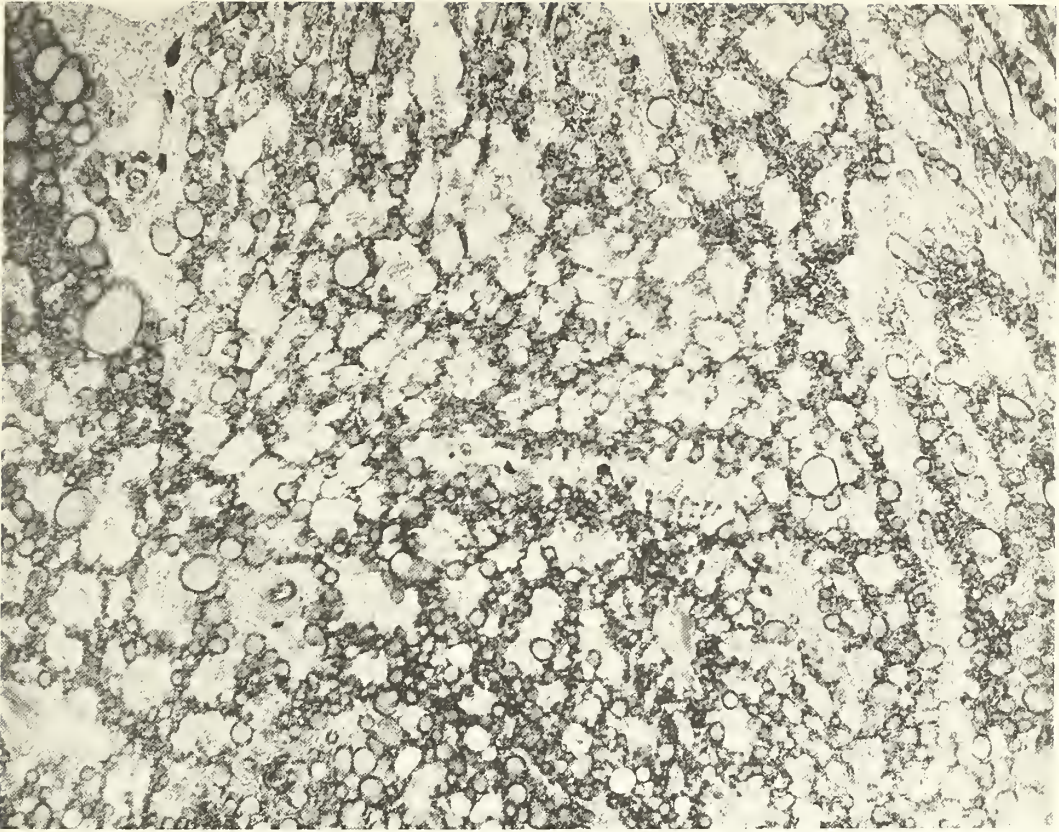


FIG. 100.—Hybrid yearling salmon. Large protruding tumor showing marked change with reversion toward normal type as the result of treatment with iodine added to the water by continuous flow in the proportion of 1:5,000,000 for 24 days. Great visible reduction in size of tumor. Fish 1083, table IX. X86.

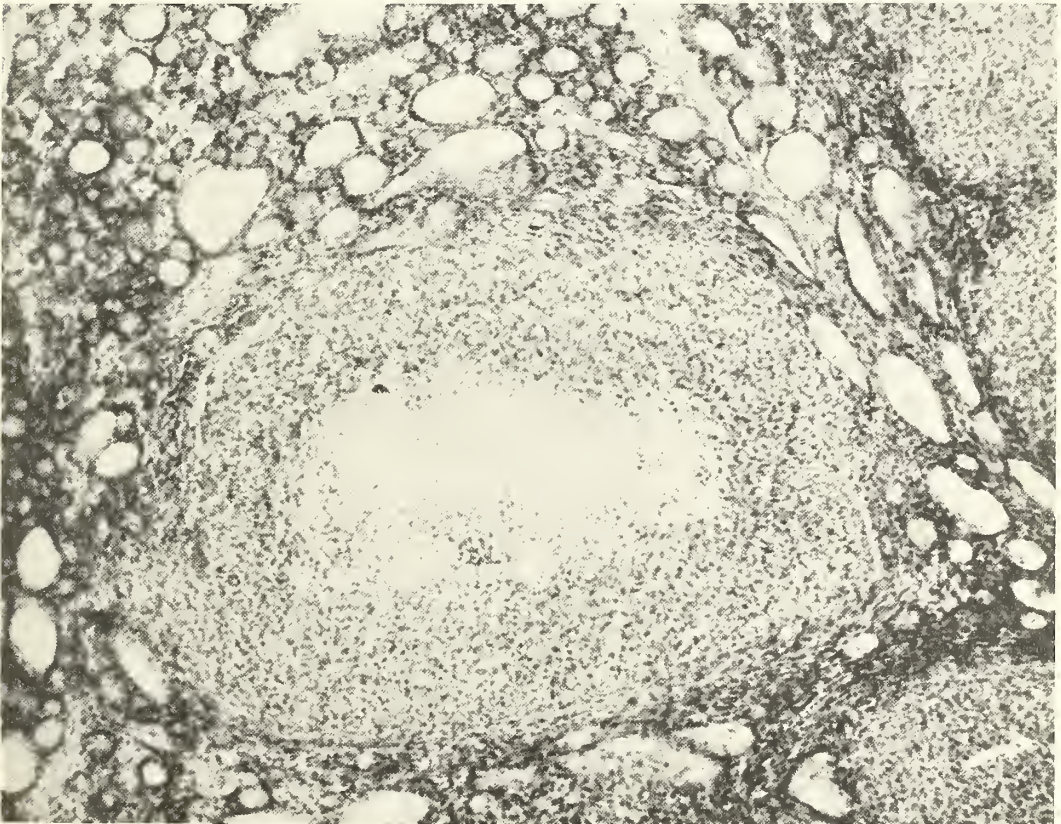


FIG. 101.—Section through tumor retrograding as the result of treatment with potassium iodide added to the water by continuous flow in a concentration of 1:5,000,000, at the end of 31 days. Large area showing organization by connective tissue, previous hemorrhage in substance of tumor induced by treatment. Great reduction in size of tumor. Fish 1060, table IX. X136.



FIG. 102.—Control for figure 103. Fish 1090, table xii. X86.



FIG. 103.—Domesticated brook trout from the same lot as figure 102, treated with bichloride of mercury added by continuous flow to the water in the proportion of 1:5,000,000 for 12 days. Disappearance of hyperplasia. Marked reversion to the normal type. Fish 1089, table xii. X86.

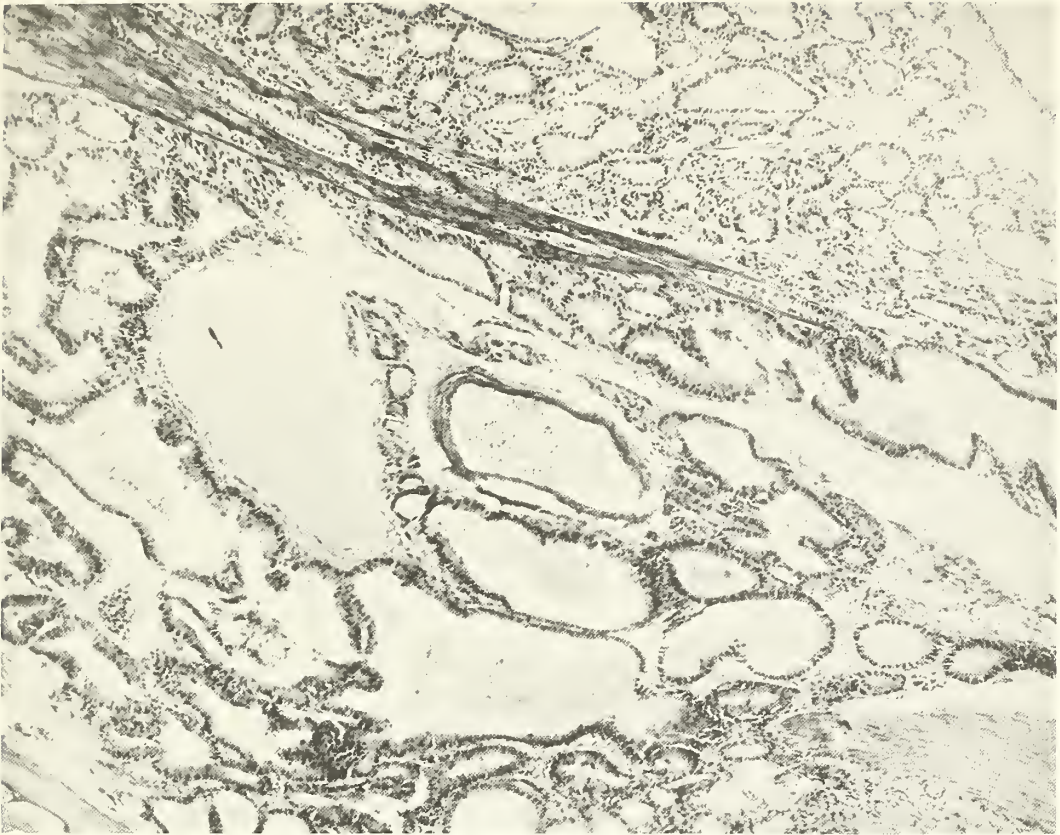


FIG. 104.—Control for figure 105. Fish 1085, table XII. X86.



FIG. 105.—Domesticated brook trout from the same lot as figure 104, treated with bichloride of mercury added by continuous flow to the water in the proportion of 1:5,000,000 for 14 days. Disappearance of hyperplasia. Marked reversion to the normal type. Fish 1084, table XII. X86.

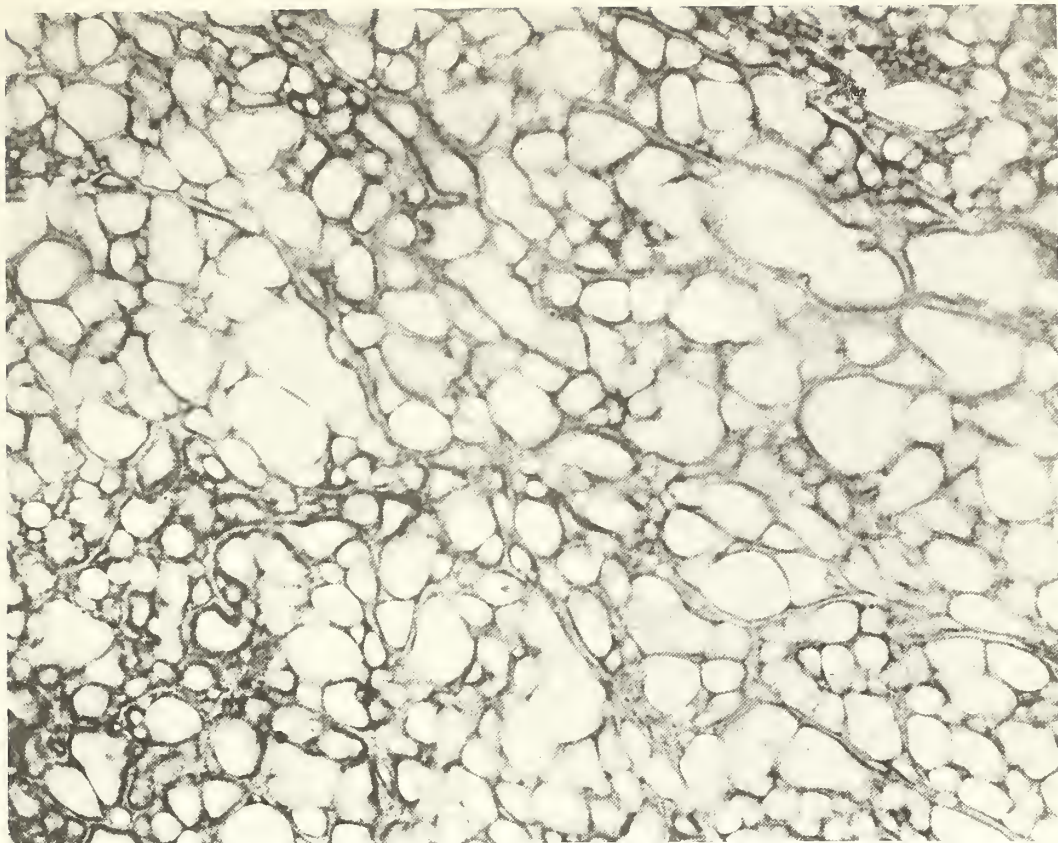


FIG. 106.—Section through large tumor domesticated brook trout which under treatment with bichloride added to the running water in the proportion of 1:5,000,000 for 3 days and then placed in standing bichloride solution 1:300,000, killed by $3\frac{1}{2}$ hours exposure. Tumor greatly decreased in size. Reversion toward normal type. Fish 1136, table XII. X86.

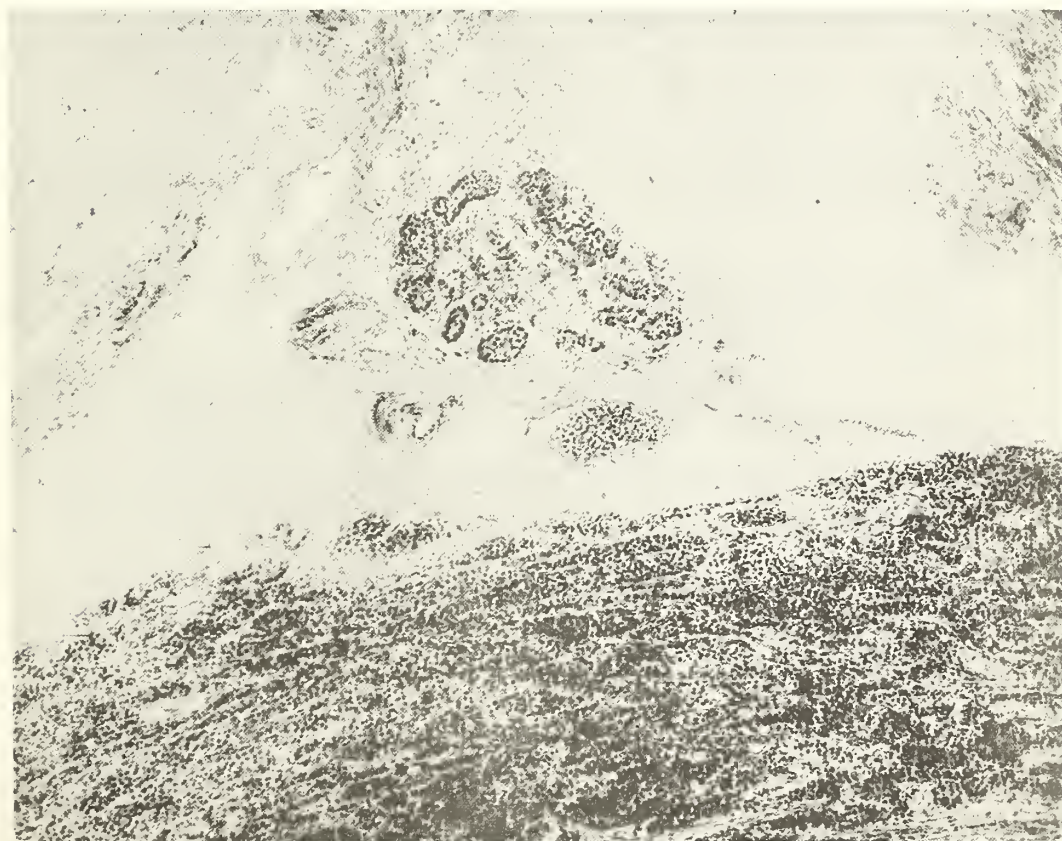


FIG. 107.—Section through margin of large tumor retrograded under treatment with bichloride of mercury 1:5,000,000 added to the water for 18 days. Marked atrophy of tumor cells, remnants of nests of cells in marginal connective tissue presenting a picture similar to regression of carcinoma in mammals. Fish 1065, table XII. X86.

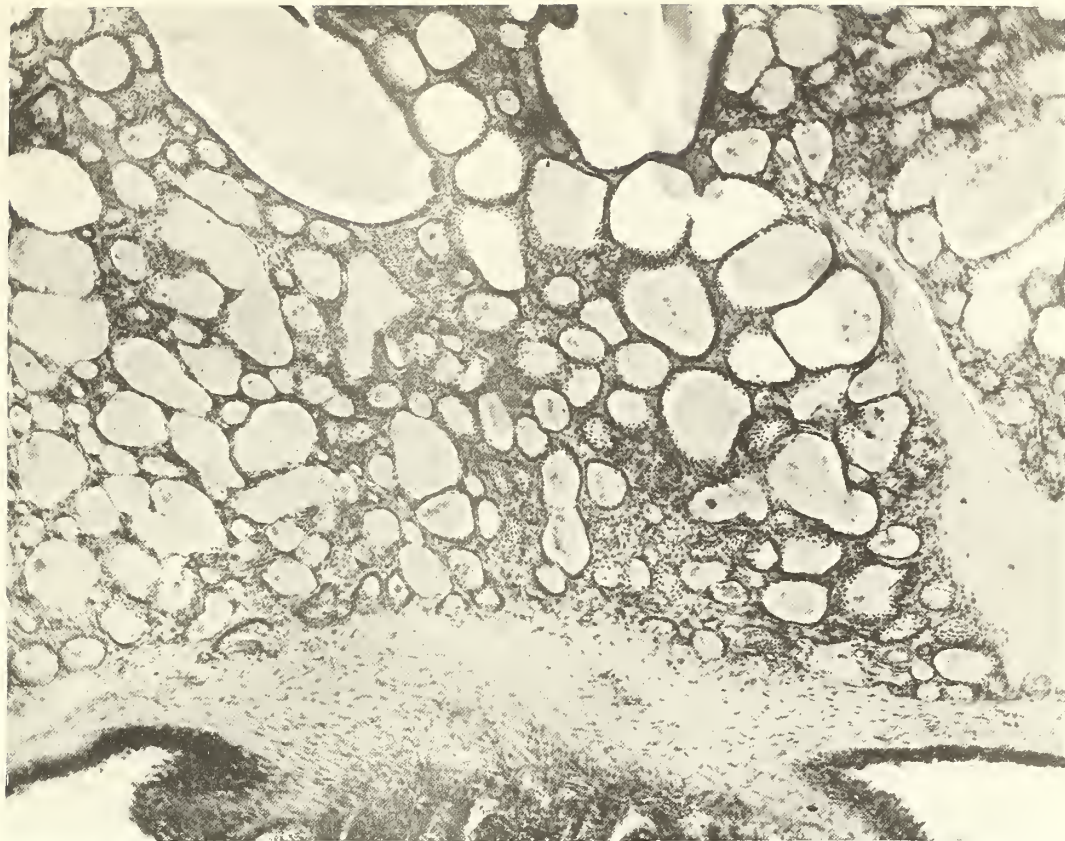


FIG. 108.—Section through tumor of two-year old brook trout treated with bichloride of mercury added by continuous flow to the water in proportion of 1:5,000,000. Result at the end of 11 days. Great reduction in size of tumor. Reversion of tumor tissue to the normal type. Fish 1144, table xii. X86.

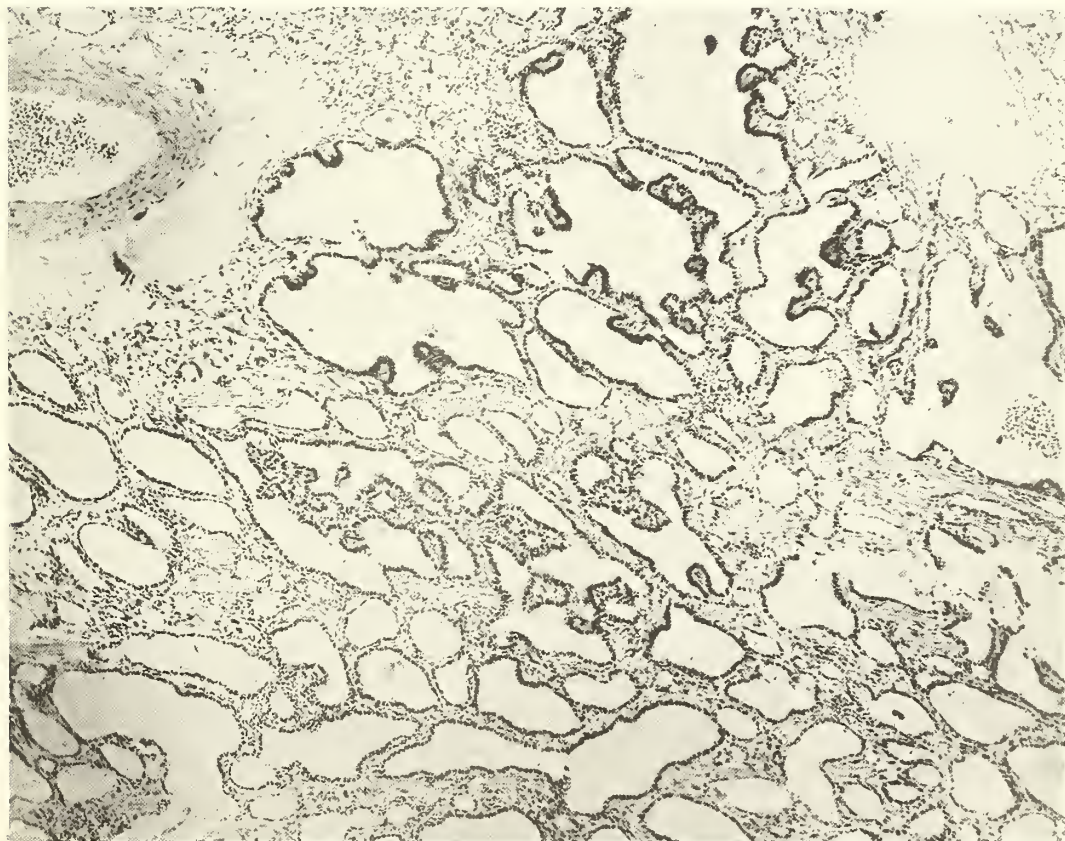


FIG. 109.—Domesticated brook trout. Visible tumor. Marked diminution in size of the tumor and marked change in tumor tissue with reversion toward normal, as the result of treating for 22 days with arsenic trioxide added by continuous flow to the water. Note marked change in epithelium. Fish 2036, table xiv. X86.

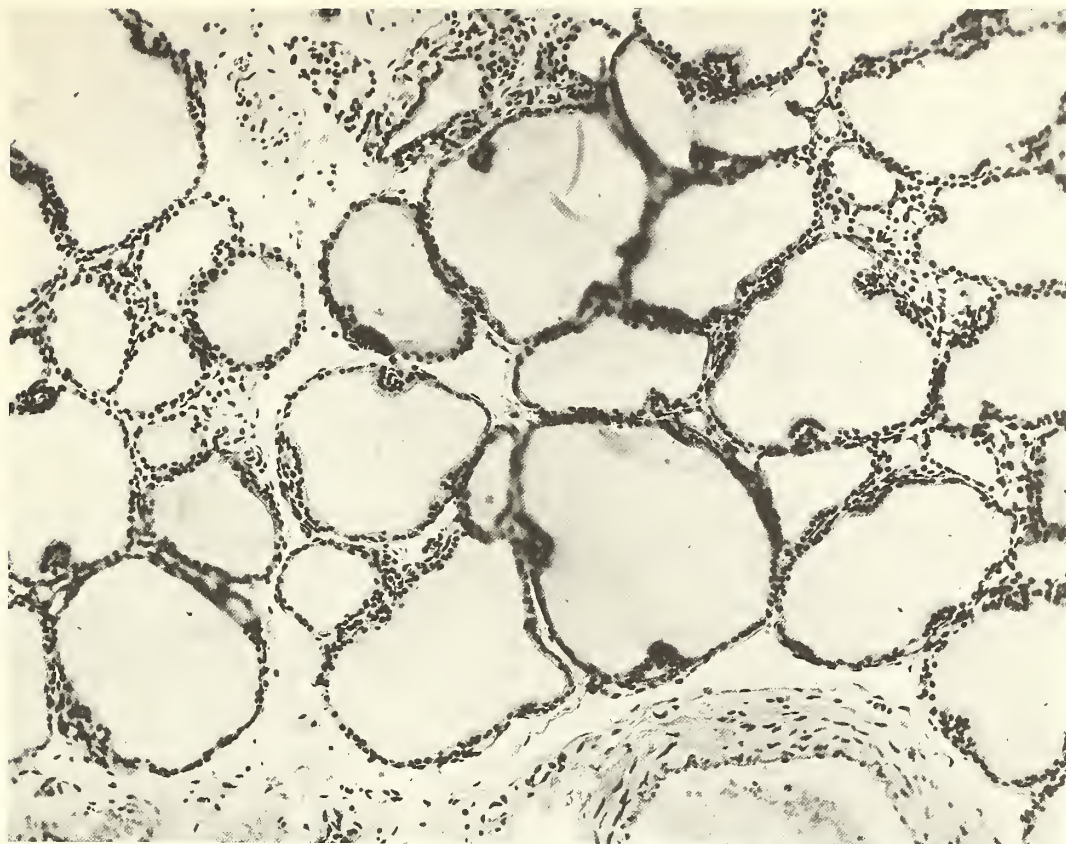


FIG. 110.—Section of thyroid of dog 21 used as control for dog 16, figure 111. Received same water as dog 16 but boiled. X160.

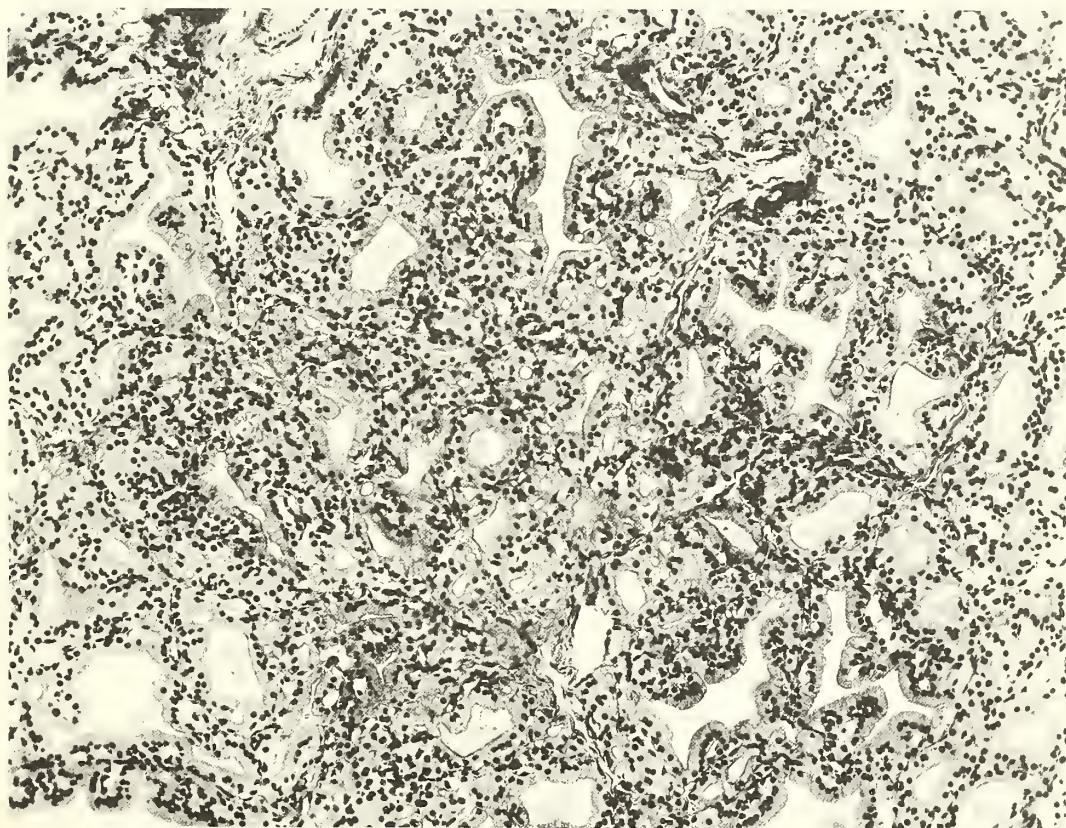


FIG. 111.—Section of thyroid of dog 16. Marked enlargement of the thyroid, well developed hyperplasia as the result of drinking water in which were suspended scrapings from fish troughs in which carcinoma of the thyroid in fish was prevalent. X160.

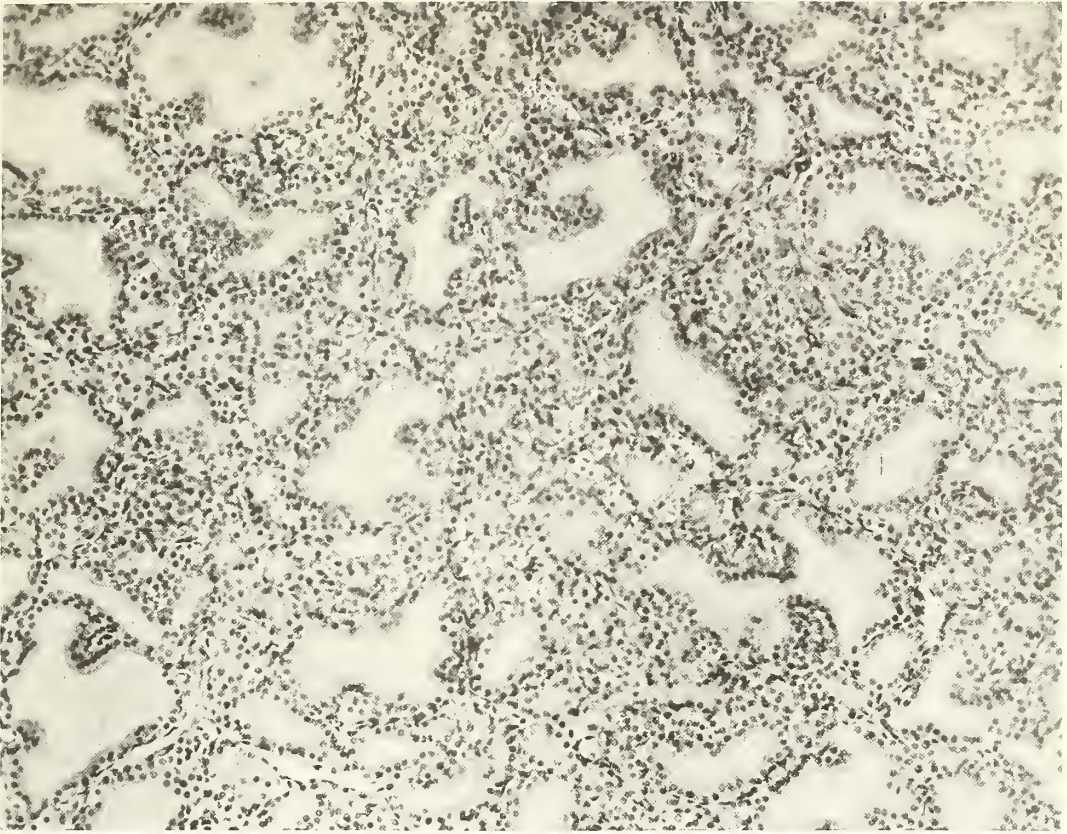


FIG. 112.—Dog. 17. Hyperplasia of the thyroid at the end of five months, from drinking water in which were suspended scrapings taken from fish troughs in which carcinoma of the thyroid was prevalent. The same experiment as dog 6, figure 111. X160.

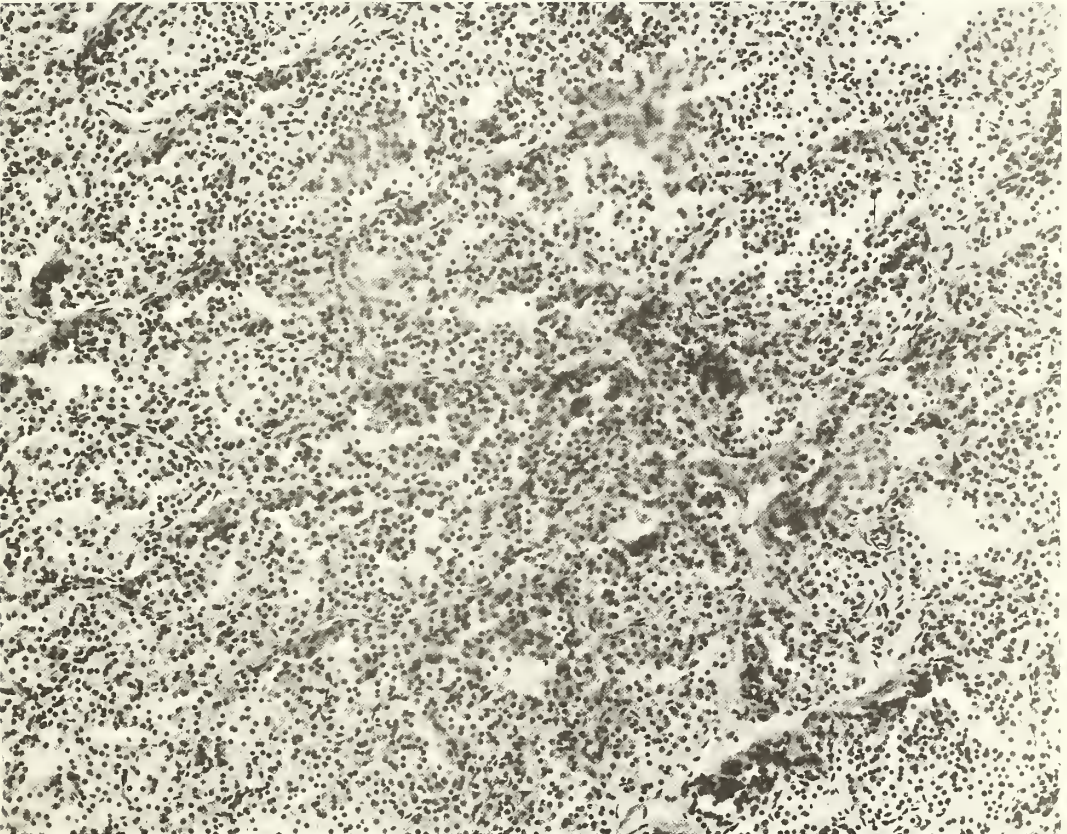


FIG. 113.—Section of enlarged thyroid of dog 15. Marked hyperplasia of the thyroid with desquamation and degenerative changes in dog drinking water with mud from pond 10, Craig Brook. X160.

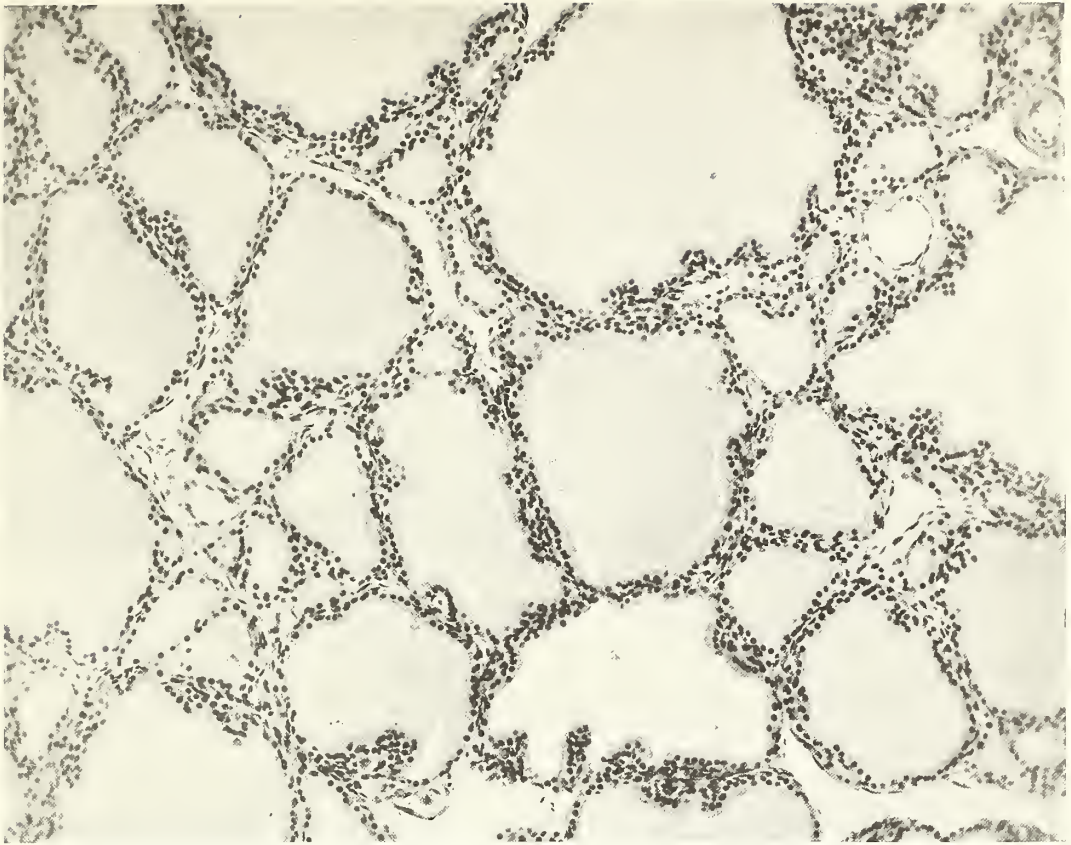


FIG. 114.—Section of thyroid of dog 20 used as control for dogs 22, 16 and 17. Received the same water as dogs 16, 17 and 22, but, like control dog 21, boiled before drinking. X160.



FIG. 115.—Dog 22. Section of enlarged thyroid. Well developed hyperplasia after drinking water five months with suspended scrapings from infected fish troughs. The same experiment and result as dog 16, figure 111, and dog 17, figure 112. X160.

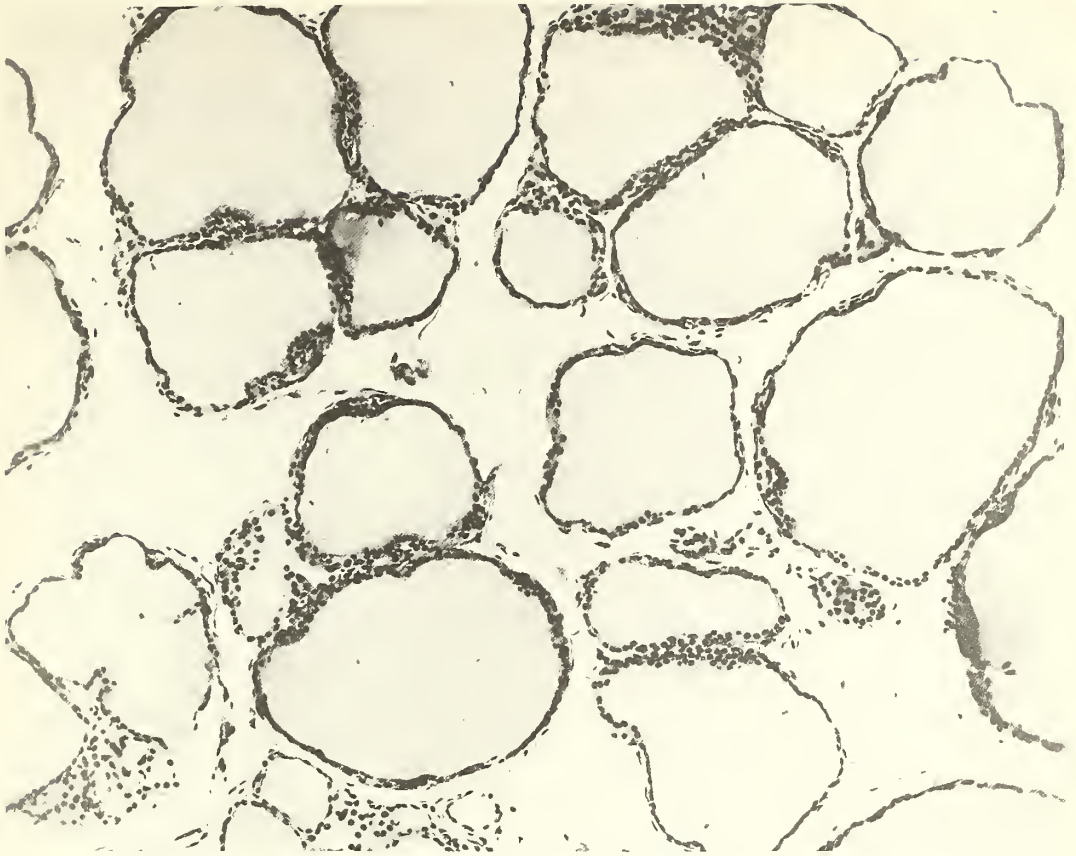


FIG. 116.—Section of normal thyroid of adult female dog, mother of dogs 15, 16, 17, 20, 21 and 22, used as control for dog 18. figure 117. Received same water but boiled before drinking. X160.

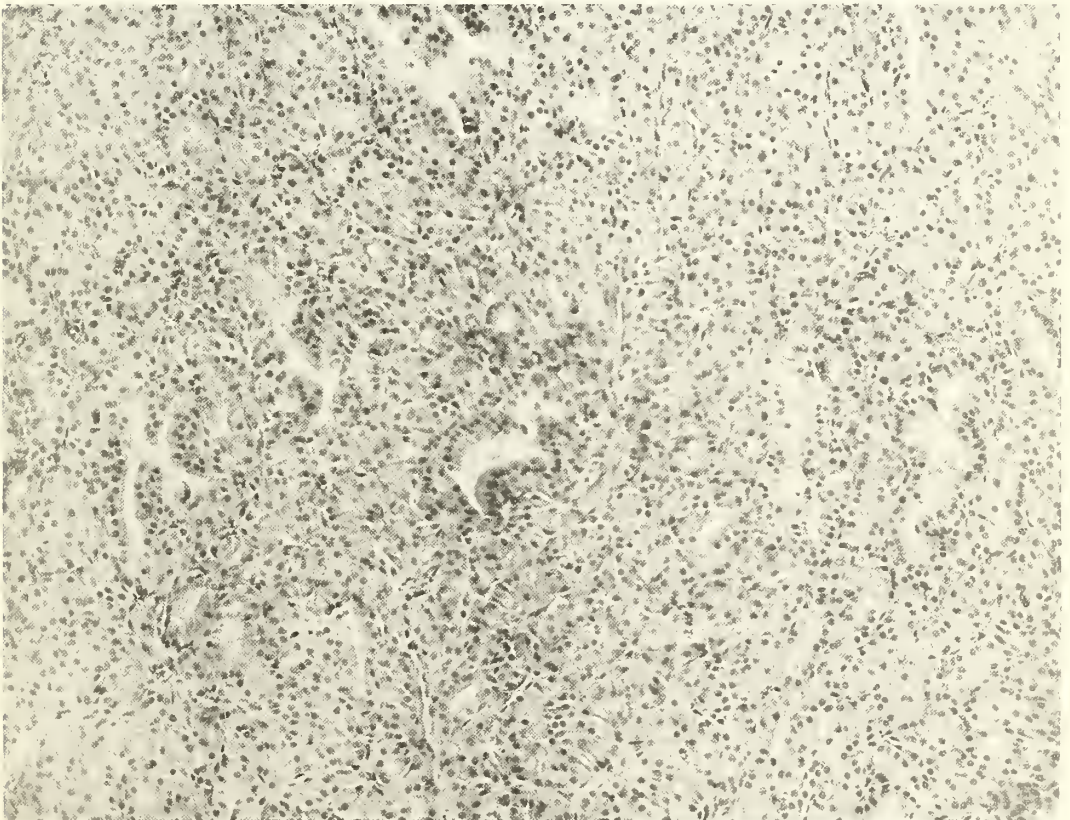


FIG. 117.—Section of markedly enlarged thyroid of adult dog 18. Result after five months drinking water in which were suspended scrapings from fish troughs in which carcinoma of the thyroid in trout was continually developing. X160.

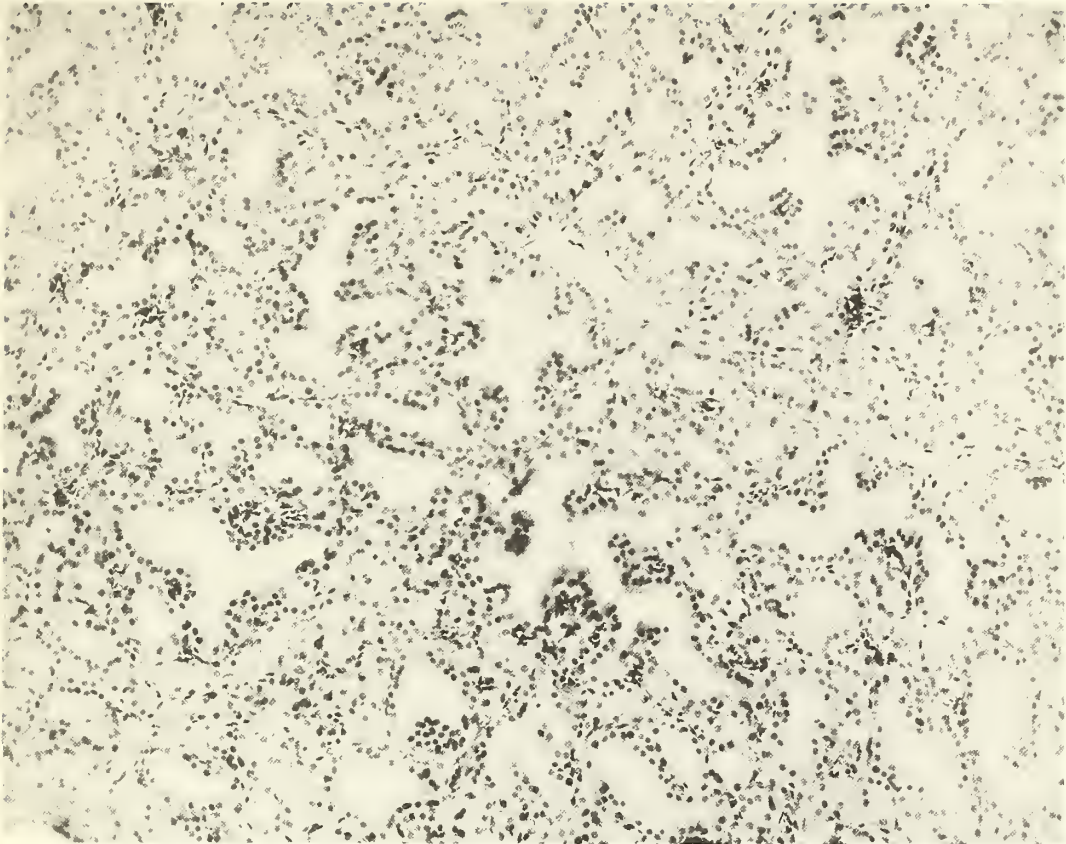


FIG. 118.—Section near periphery of enlarged thyroid of dog 18. The process is less intensive than near the center, as illustrated in figure 117 and 119. Columnar epithelium, marked papillary growths into distorted alveoli. Colloid absent. X160.

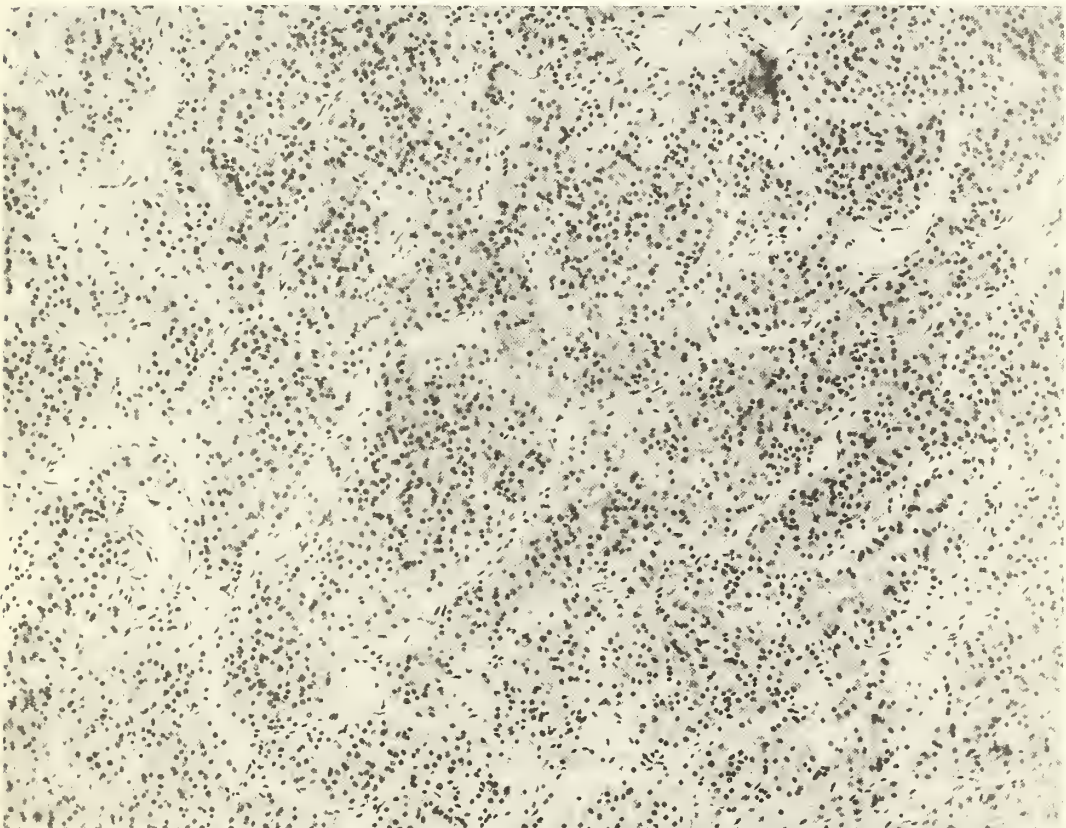


FIG. 119.—Section from center of enlarged thyroid of dog 18, showing large conglomerate masses of cells, deeply staining nuclei, coalescing protoplasm. Picture similar to the acute infectious thyroiditis of de Quervain, and diffuse parenchymatous goiter produced in dogs by Bircher by the administration of water from goitrous wells. X160.

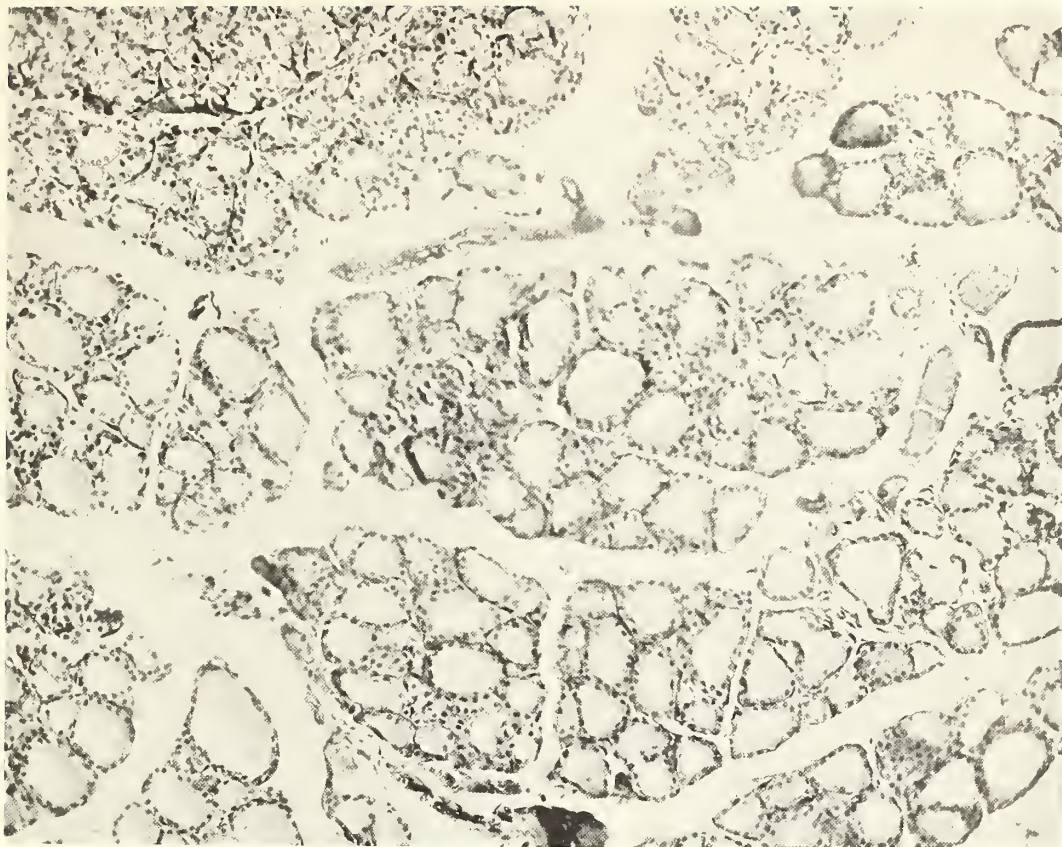


FIG. 120.—Normal thyroid gland of rat 32 used as control for rat 115, figure 121. X160.

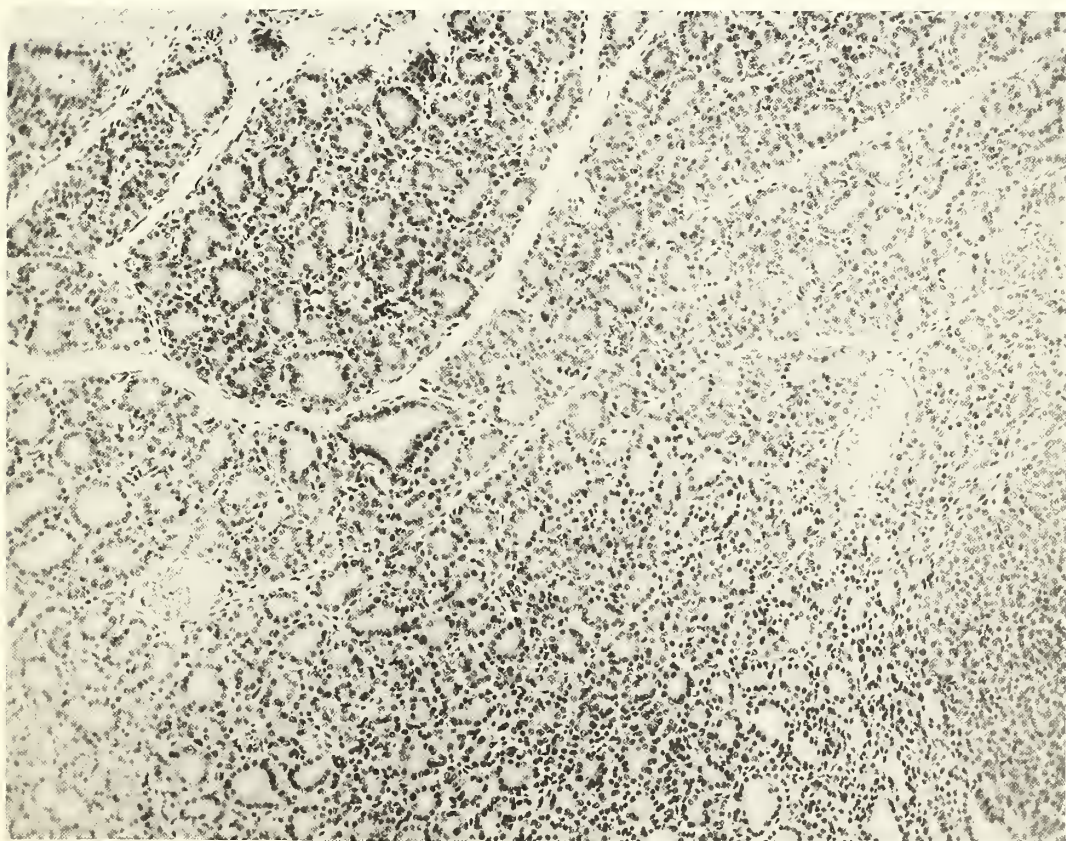


FIG. 121.—Hyperplasia of thyroid in rat at the end of 90 days, from drinking water with suspended scrapings from infected fish troughs from Craig Brook, Maine. Experiment conducted in Buffalo. X160.

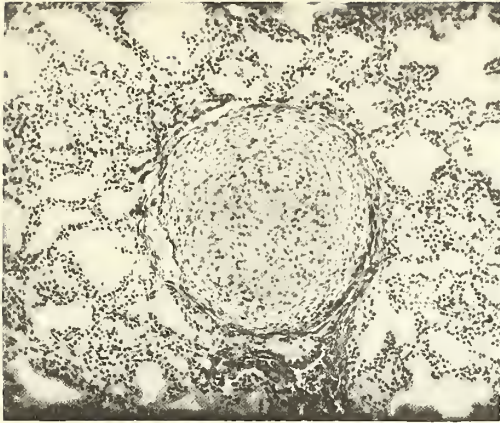


FIG. 122.—Section of dog's thyroid showing tubercle with cross section of nematode in capsule. X70.

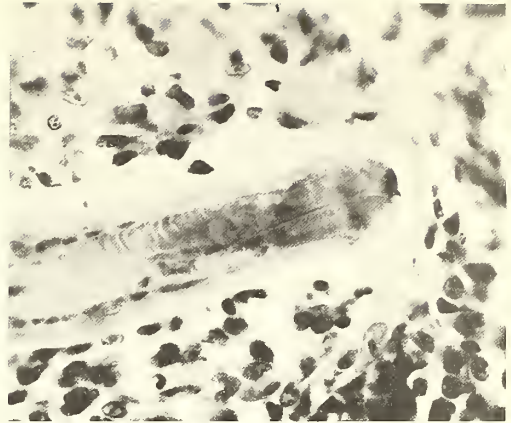


FIG. 123.—Section showing head of nematode inclosed in tubercle. X550.

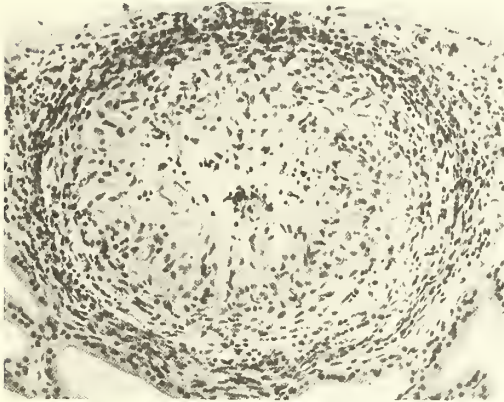


FIG. 124.—Cross section of nematode in center of tubercle, in dog's thyroid. X130.

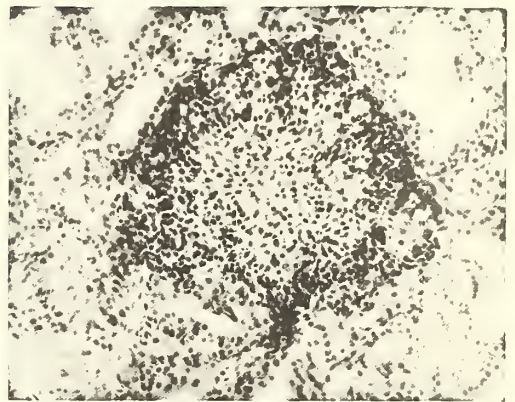


FIG. 125.—Healed tubercle showing no evidence of nematode. X130.

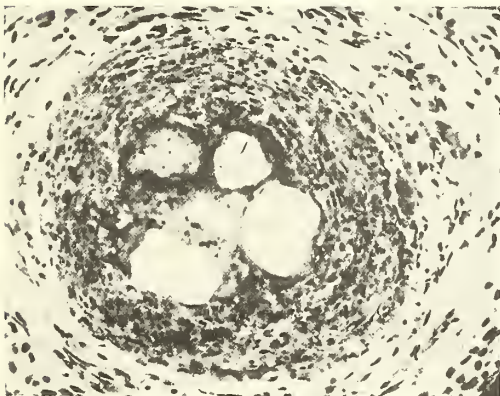


FIG. 126.—Section of tubercle in fish showing spaces evidently occupied by nematode. X240.

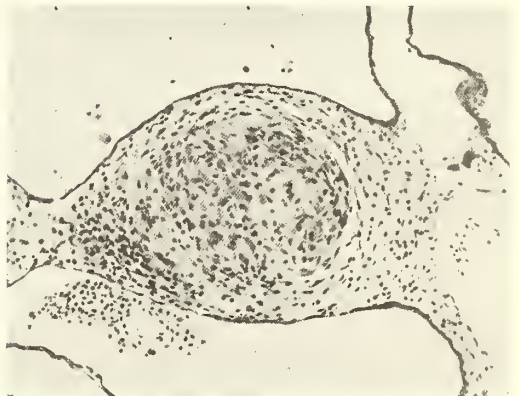


FIG. 127.—Section showing healed tubercle in fish. X130.

A LIMNOLOGICAL STUDY OF THE FINGER LAKES
OF NEW YORK



By Edward A. Birge and Chancey Juday
Wisconsin Geological and Natural History Survey
Madison, Wisconsin

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A LIMNOLOGICAL STUDY OF THE FINGER LAKES OF NEW YORK.



By EDWARD A. BIRGE and CHANCEY JUDAY,
Wisconsin Geological and Natural History Survey, Madison, Wisconsin.



INTRODUCTION.

In 1910 the authors of this paper were enabled to visit the Finger Lakes district of New York, through a grant from the United States Bureau of Fisheries, and the month of August was spent in work upon the lakes. In February, 1911, Mr. Juday visited four of the lakes to secure winter temperatures. A week in August and September, 1911, was used in obtaining a second set of summer temperatures. The temperatures of Skaneateles and Owasco Lakes were also taken in February, 1912, and in the early autumn of that year.

The purpose of the investigation was to extend to these lakes the studies on dissolved gases, plankton, and temperatures, which the authors had already made on the lakes of Wisconsin.^a The lakes of New York are peculiarly well adapted for such study. Four of those visited—Canadice, Otisco, Conesus, and Hemlock—are directly comparable with several of the lakes of Wisconsin in size, depth, and biological conditions. The others, beginning with Owasco Lake, form a series whose smaller members are not greatly different from Green Lake, Wis.; but whose largest members, Cayuga and Seneca, are the largest inland lakes^b (except Lake Champlain) and the deepest in the United States east of the Rocky Mountains. Still further, these lakes lie in a region whose topography is hilly, but not mountainous. The highest elevations close to the lakes do not exceed 300 meters (1,000 feet) above the water, and the immediate slopes are, in general, much lower. The lakes, therefore, are not exposed to the peculiar climatic conditions of mountain lakes, but in general these conditions are comparable with those which exist in Wisconsin.

Seneca Lake, the deepest in the district (188 meters, 618 feet) is much exceeded in depth by lakes in Europe. A score or more are found there which are comparable in size and form, but which reach a greater depth. Some nine European lakes exceed a depth of 1,000 feet. Yet Seneca Lake is so deep that from a biological point of view it offers conditions of life not essentially different from those of the deeper European lakes, and physically also it is essentially similar. These lakes are therefore directly

^a Birge, Edward A., and Juday, Chancey: The inland lakes of Wisconsin: The dissolved gases of the water and their biological significance. Wisconsin Geological and Natural History Survey, Bulletin xxii, Scientific Series No. 7, 259 p. 1911.

^b It may be noted here that the term "inland lakes" is used by us in contrast to "Great Lakes," which latter name we should apply only to the lakes of the series from Superior to Ontario.

comparable with the larger and deeper lakes of Europe, although such a comparison is reserved by us for another paper.

There is another circumstance which makes it possible to study the Finger Lakes profitably. The hydrography of the six chief lakes has been determined through surveys made by Cornell University. These will receive more detailed notice in a later section. The successive classes of the College of Civil Engineering, Cornell University, carried on studies of these lakes almost continuously from 1874 to 1897, devoting to the field work a period each summer following the closing of the college year. The university published maps giving the outlines, soundings, and shore topography (so far as the last was determined) for Cayuga and Seneca Lakes (scale 1:60,000), Canandaigua and Keuka Lakes (scale 1:40,000). Owasco Lake was published privately in similar manner. Otisco and Skaneateles Lakes have remained unpublished. Both the published maps and copies of drawings of the unpublished lakes have been placed at our disposal by Director E. E. Haskell, of the College of Civil Engineering, Cornell University, to whom our thanks are due for many courtesies.

This work has had a singular fate. No limnologist appears to have made use of it, or, indeed, to have known of it. The volume, mean depth, etc., of the lakes can be determined from the data supplied by these surveys; but until the authors of this paper undertook the task it had not been done. The earliest survey was that of Cayuga Lake, begun nearly 40 years ago. It was the first to be made of an inland lake in the United States and antedates most similar surveys in Europe; but it seems to be almost wholly unknown, as well as the surveys made later. The lakes are not mentioned in Murray's ^a account of the lakes of the world or in Halbfass's account of the lakes outside of Europe.^b Yet these are the only lakes in the eastern United States which are at all comparable to the more important inland lakes of Europe and the surveys represent a quality of work which has been surpassed by only the best European surveys.

A very careful hydrographic survey of Canadice Lake was made by the department of water supply of Rochester, N. Y., and the authors express their thanks for a copy of this map, as well as for the other courtesies rendered by the department.

This paper represents the joint work of the authors. Mr. Juday is, however, directly responsible for the sections on gases and plankton and Mr. Birge for those on hydrography and temperatures.

METHODS AND AUTHORITIES.

In the account of the physical geography and hydrography ^c of the Finger Lakes the elevations above sea level are taken from the maps of the United States Geological Survey. The figures for the areas, depths, and slopes of the lakes are derived from the

^a Murray, J.: The characteristics and distribution of lakes. Bathymetrical survey of the fresh-water lochs of Scotland, vol. 1. Edinburgh, 1910.

^b Halbfass, W.: Topographie, Hydrographie, Geologie der Ausser-Europäischen Seen, in Der Gegenwärtige Stand der Seenforschung, bd. 1, 1912.

^c Tarr, R. S.: Popular Science Monthly, vol. LXVIII, p. 387-397; United States Geological Survey, Folio No. 169, p. 4, 1910.

Watson, T. L.: Fifty-first annual report of the New York State Museum, vol. 1, p. 159-1117 (1897), 1899.

Nevius, J. N.: Ibid., p. 1131-1152.

Rafter, G. W.: Hydrology of the State of New York. New York State Museum Bulletin 85, 1905.

maps of the Cornell survey for all lakes except three. Canadice Lake was surveyed by the Rochester water department, and no hydrographic survey has been made of Conesus and Hemlock Lakes. The facts regarding their area have been taken from the maps of the United States Geological Survey and those of depth come from the observations of the authors.

The style of publication for the maps of the six lakes surveyed by Cornell University was a matter that caused much hesitation. The authors would have preferred for many reasons to use the metric system, but they decided on the use of the foot-and-mile scale in order to show the shore topography by means of the maps of the United States Geological Survey. These topographic maps are engraved on this scale, and it was easy to insert the hydrography on the plates, while the cost of reengraving the topography on the metric scale was prohibitive.

All of the primary measurements are based on the metric system. Each sounding was converted from feet to meters before being platted on the working maps. The maps were enlarged to twice the scale of the original or to four times that scale in cases where the slopes were steep and the contours crowded. The measurements of areas were made with great care and repeated. It need not be stated that the number of soundings, especially in Cayuga and Seneca Lakes, is not enough to insure great accuracy of detail in the contours; but as all of these lakes are simple, straight, narrow, steep-sided troughs, without islands, bays, or marked irregularities of outline or of bottom, the results are approximately correct, and no subsequent survey is likely to make substantial alterations in them.

The contour interval of 10 meters was chosen for the primary measurements because of the nature of the temperature curve. The epilimnion is from 9 meters to 15 meters thick, and for computing temperatures the volume of the 0-10-meter zone, etc., must be known. In the small lakes the contour interval is 5 meters. For determining the volume of the several lakes the areas bounded by the several contours were measured, the volume of each zone was computed, and the total volume of the lakes as given in table I is the sum of the volumes of the several zones.

In the detailed tables of the appendix the areas and volumes of the lakes are given in feet as well as in meters. The primary computations were all made on the metric system and the areas of the lakes at the 50-foot or 25-foot contour intervals were derived, not from the replatting of the lakes for engraving the maps, but from the hypsographic curves derived from the metric measurements. These areas agree essentially with those shown on the maps, but of course small differences appear.

In preparing the maps for the engraver the Cornell soundings were platted on the outlines of the United States Geological Survey maps and the contours drawn again for this purpose.

The Cornell maps are based upon a detailed survey of each lake; not only were the lakes sounded but their outlines were determined by a careful trigonometrical survey. The sounding line was of wire; an apparatus was provided for releasing the weight when the bottom was reached and a registering apparatus recorded the depth. The first machine employed is no longer in existence, but the second one, and that

with which most of the work was done, is still in good condition. It was recently calibrated and found accurate. There is every reason to believe that the earlier instrument was equally good. The soundings were well placed and the position of each was controlled by transit instruments on shore and a sextant in the boats. Every care, therefore, was used to secure accuracy in detail.

All of the under-water contours, both for the working maps and for the engraver, were drawn by Mr. L. S. Smith, associate professor of topographic engineering in the University of Wisconsin.

TOPOGRAPHY AND HYDROGRAPHY OF THE FINGER LAKES DISTRICT.

GENERAL ACCOUNT.

In the central part of the State of New York lies a plateau composed of nearly horizontal strata of soft Devonian shales and sandstones, whose highest points reach an elevation of about 700 meters (2,300 feet) above the sea. That part of this region with which this paper deals is known as the Finger Lakes district. (See sketch map, fig. 1.) It is bounded on the west by the valley of the Genesee River, which extends completely across the State. From this it extends about 140 kilometers (84 miles) eastward to the eastern tributaries of the Seneca River. It occupies the northern slopes of this plateau, with a maximum breadth of about 70 kilometers (40 miles). The meridian of 77° lies close to the center of the district, and it is bounded on the north by latitude 43° .

Lake Ontario lies about 40 kilometers (25 miles) to the north of this region. The district between the base of the plateau and Lake Ontario is deeply buried in drift whose surface is shaped into innumerable drumlins. The surface of the plateau itself bears but little drift. Its hills have been little eroded, but its valleys have been smoothed, widened, and deepened by the continental glacier.

The waters of the western one-fifth of this district drain into Lake Ontario by the Genesee River, which flows almost directly north to the lake. Across the north front of the remainder of the district flows the Seneca River, which has its origin in Seneca Lake, but is continued to the west by the Clyde River and the creeks that constitute the headwaters of that stream. The two rivers have a course in general almost directly east for 100 kilometers (60 miles) flowing between the base of the plateau region and the drift-covered region to the north. The stream has found out for itself a course, twisting about among the groups of drumlins in an imperfectly developed valley, which offers very little slope for its flow, so that large marshes are developed. This valley has furnished the course for the Erie Canal. The Seneca River empties into the Oswego River, which flows nearly north, directly into Lake Ontario.

The chief tributaries of the Clyde and Seneca Rivers come from the plateau to the south, which is deeply trenched by their valleys. Some nine principal valleys extend southward into the highlands for a distance varying from 40 kilometers or less at the eastern and western limits to nearly 100 kilometers in the center. These valleys are nearly parallel. (See fig. 1.) Those in the center extend almost exactly from north to south. Those to the east diverge eastward and those to the west have a westward inclination.

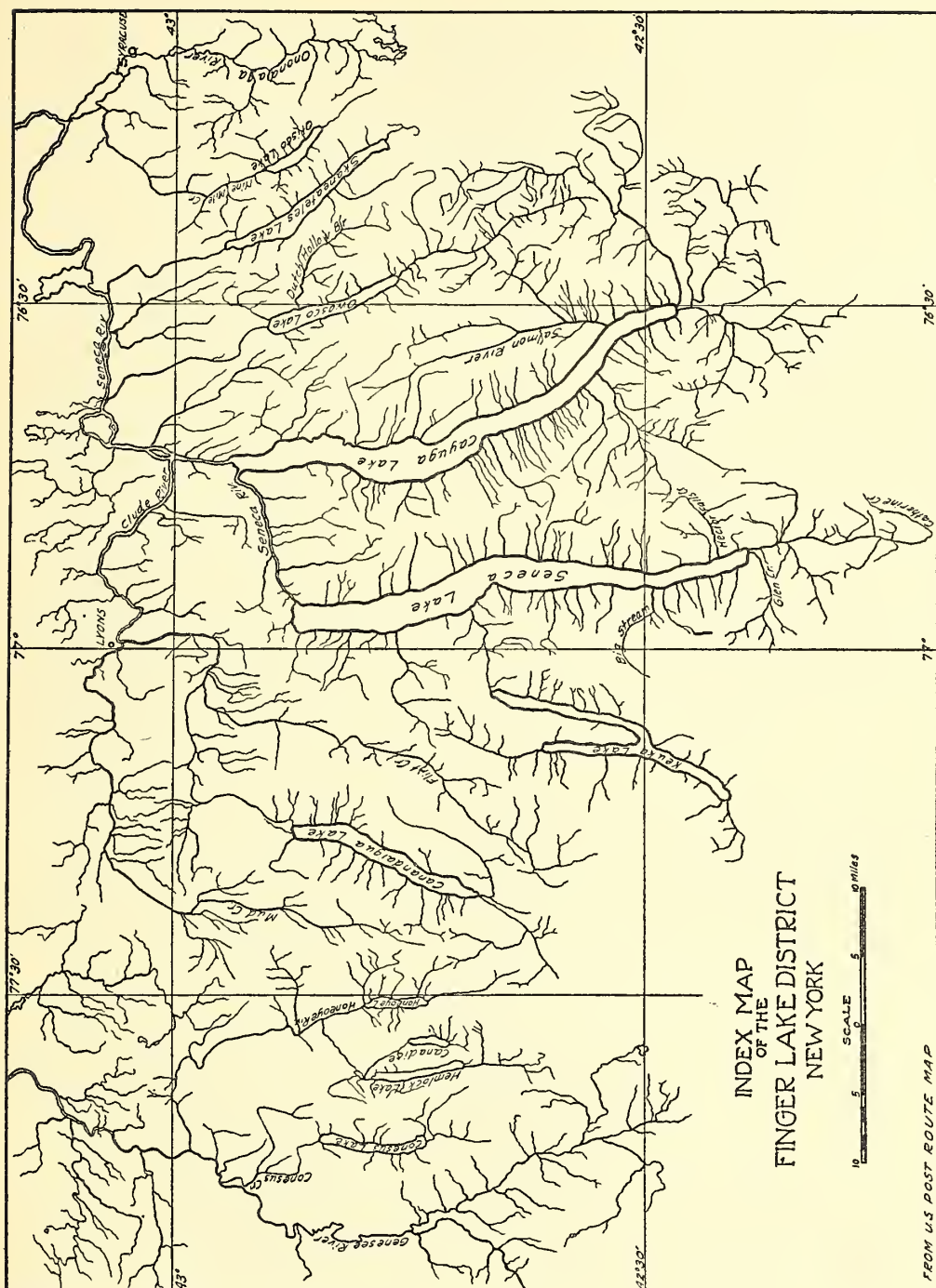


FIG. 1.—Index map of the drainage of the Finger Lake district. Scale about 1: 872,000; 1 inch = 12.8 miles; 1 cm. = 8.5 km.

The chief towns on the lakes are: Canandaigua at the foot of Canandaigua Lake; Penn Yan at the foot and Hammondsport at the head of Keuka Lake; Geneva at the foot and Watkins at the head of Seneca Lake; Seneca Falls on Seneca River west of the outlet of Cayuga Lake and Ithaca (the seat of Cornell University) at the head of Cayuga Lake; Auburn at the outlet of Owego Lake; Skaneateles at the foot of Skaneateles Lake.

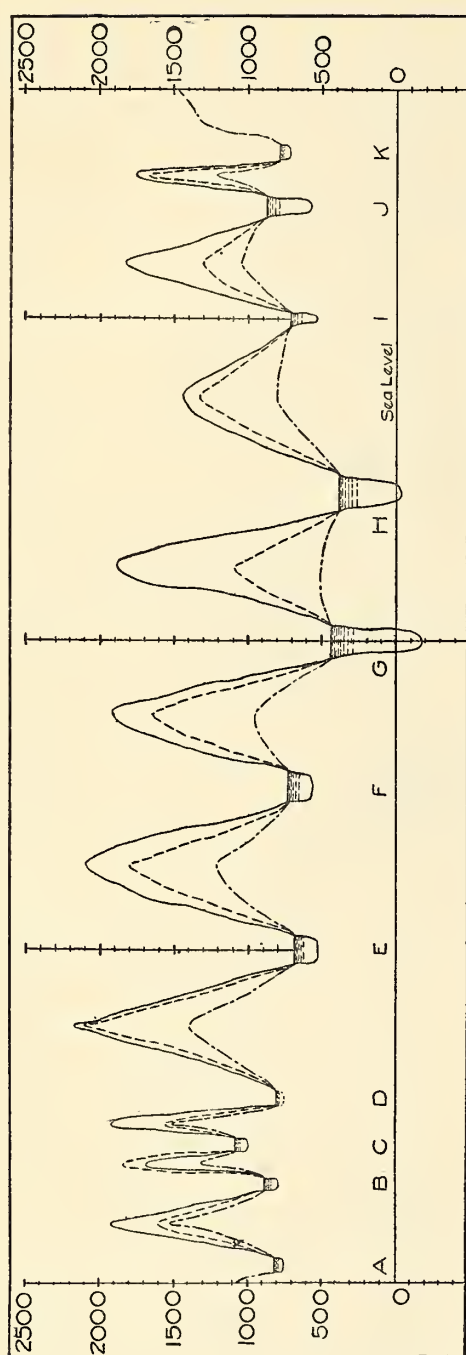


FIG. 2.—Diagram showing elevation above sea level and depth of the lakes, and elevation of the ridges between them. Modified from Reed and Wright, *Vertebrates of the Cayuga Lake Basin*, N. Y., Proceedings of American Philosophical Society, vol. xlviii, 1909, pl. xix. Vertical scale 100 times horizontal. Elevations in feet. The sections of the lakes pass through the deepest part of each lake. Those of the ridges are on lines drawn from lake to lake and not on lines straight across the district. The full line shows the section near the south end of the lakes; the broken line is near the middle; the line with alternate dots and dashes is near the north end. These sections show the increase of height toward the south, especially in the case of the major lakes. The smaller lakes lie in general farther back from the north end of their valleys and this condition is not so marked. The lakes are as follows: A, Conesus; B, Hemlock; C, Canadice; D, Honeoye; E, Canandaigua; F, Keuka; G, Seneca; H, Cayuga; I, Owasco; J, Skaneateles; K, Otisco.

All of these valleys are occupied by streams. In the westernmost valley and in the second one to the east from this are found two of the creeks that unite to form the Clyde River. In the easternmost valley is found one of the branches of the Onondaga River. The remaining six valleys have been much modified and deepened by glacial action and are filled in part by long, narrow, relatively deep lakes. These are the Finger Lakes, so called from their form and because they diverge somewhat as do the outspread fingers from the hand. The seventh lake of this series, Keuka Lake, occupies a branching valley which seems to have drained originally to the south. It was worked over by the ice in a way similar to the other lake-filled valleys, and now drains by a post glacial stream into Seneca Lake.

The valleys occupied by these lakes are undoubtedly of preglacial origin, but they were profoundly altered by the invasion of the ice. Seneca and Cayuga Lakes extend below the level of the sea (see fig. 2), the deepest parts of the Seneca Basin being 53.5 meters (180 feet) below sea level and those of Cayuga 16.4 meters (54 feet). These figures do not represent the maximum depth of the valleys. In the flat at Watkins, near the south

end of Seneca Lake, a boring was carried down over 300 meters (1,000 feet) without reaching the rock, and similar borings at Ithaca have found loose material at greater depths than the maximum depth of Cayuga Lake. We are not aware that any similar observations have been made in the other valleys.

Between the westernmost tributary of the Clyde River and the Genesee Valley are four short, steep-sided valleys, deeply cut into the highlands, which here extend well toward the north part of the plateau. Each of these contains a lake similar in form to the lakes of the Seneca Basin, but much smaller and shallower than any of these except one. The outlets of these lakes also flow north, but soon turn west and reach the Genesee River by a short course.

In this district, therefore, lie 11 larger lakes, each of them occupying a major valley in the north slope of the highlands (see fig. 1), a valley which in all cases but one opens independently upon the front of the highlands. The northern ends of these lakes are near the north end of their respective valleys and, in general, are not far from the same latitude. This is especially obvious in the five lakes that occupy the central and larger valleys. To the south these lakes extend for a longer or shorter distance in proportion to their length, being longer in the center of the region and shorter, in general, toward the east and west limits.

In the center of this district the relatively low land of the Seneca Valley extends southward in a broad lobe. In the two valleys of this region lie Seneca and Cayuga Lakes, nearly parallel to each other and of almost exactly equal length and area. They are by far the largest and deepest lakes of the series. East of Cayuga and west of Seneca lie two other major lakes, Owasco and Skaneateles to the east and Keuka and Canandaigua to the west. East of Skaneateles Lake lies a single lake, Otisco, much smaller and shallower than any of the six; while to the west of Canandaigua come Honeoye, Canadice, Hemlock, and Conesus Lakes, constituting the series of four small lakes belonging to the Genesee Basin.

Thus the largest, deepest, and least elevated of these lakes lie in the center of the group. The elevation of the surface of the lakes increases in general from these toward the east and the west, declining somewhat at the extreme ends of the series. (See fig. 2.)

The lakes which lie immediately east and west of Seneca and Cayuga are similar in depth, though not in area. Owasco is considerably smaller than Keuka, but each is between 50 and 55 meters in maximum depth. The two lakes which lie next to the east and west, Skaneateles and Canandaigua, resemble each other very closely in length, area, depth, and topographic surroundings. Two lakes 70 kilometers apart can hardly resemble each other more closely than do these. As the table shows, they are considerably larger and much deeper than Owasco and much deeper than Keuka, although smaller in area. These six major lakes, in spite of their differences, belong to the same general class, as is shown by their dissolved gases and temperature. The small lakes lying still farther to the east and west are lakes of a different class, as the same series of facts will show. None of them reaches 30 meters in depth, and in area the largest of them is not a quarter the size of the smallest of the major lakes.

The ridges between these valleys rise in general to a maximum height of about 600 meters (1,800 to 2,000 feet) above the sea or 300 to 400 meters (1,000 to 1,500 feet)

above the lakes. Since the lakes extend to the north ends of their respective valleys, where they open into the valley of the Clyde-Seneca River, the altitude of the ridges is in general lower at the northern end, where the valleys are also wider and the slopes of their sides are less steep. (See fig. 2.) To the south the valleys narrow, their sides become steeper, and the height of intervening ridges increases. These characters are most marked in the valleys of the larger lakes, perhaps most conspicuous of all in Cayuga Lake, which at one end extends deep into the highlands at the south and at the other reaches farthest into the valley of the Seneca River, so far, indeed, that it is continued to the north by the extensive marshes that bound its outlet.

The immediate shores of the lakes are smooth and regular. They have a steep slope, which toward the south may rise above the lake to a height of 100 to 150 meters (300 to 400 feet) or more. Above this altitude this slope rises more gradually to the general level of the plateau, and then comes a steeper rise to the higher elevations.

The tributary valleys on the upland slopes are broad, and the lower and steeper slopes are trenched by innumerable narrow gorges. These range in size from gullies which serve to carry off the rains, but are usually dry, to picturesque gorges, cut deep into the rocks and occupied by considerable streams. Of these last the most famous are Watkins Glen at the south end of Seneca Lake and the several gorges at the south end of Cayuga Lake.

The smoothly outlined shores of these lakes show few irregularities or decided projections except where the axis of the lake bends on account of the course of the original valley. Long Point on Seneca Lake is an instance of such a structural projection. Cayuga Lake has a broad expanse of shallow water at the north end, and here there are several points and one small island (the only island in the series of lakes) which represent irregularities of the original shore. The maps show similar conditions in less marked degree at the north end of other lakes. In general, however, the irregularities of the water line are small and are due to flat deltas and spits built by the tributary streams and by the waves. These constitute a characteristic and very beautiful feature of the shores of the lakes. They vary greatly in size according to the drainage basin of the stream that produced them. The maps of the lakes show numerous examples of such points; Myers Point on Cayuga Lake is perhaps the largest; and the flat on the west side of Seneca Lake on which the town of Dresden is situated was built in similar fashion by the outlet of Keuka Lake. In Conesus Lake (fig. 3) two such points opposite each other near the middle of the lake have nearly divided it.

The form of the lakes and their steep banks have so directed the course of the winds that very little work has been done by the waves along their sides. As a result, the wave-cut shelf is very narrow and the water deepens close to the shore and very rapidly. Few large tributaries enter the lakes by their sides; most of the larger streams enter at the south end. (See fig. 1.)

The larger lakes of the Seneca Basin take in and give out during the year an amount of heat whose aggregate is enormous. It has been computed that this is equal to the heat generated by the combustion of nearly 150,000 tons of coal for each square mile of the surface of the lake. The total amount of heat from Seneca Lake would equal that from nearly 10,000,000 tons of coal. This heat is absorbed by the water in the

spring and liberated in autumn and produces a considerable local effect on the climate. The effect is intensified by the narrow valleys with their steep slopes which concentrate and localize the influence of the water. Frosts are delayed in autumn, and in spring the cold water chills the air of the valleys so that vegetation does not start until the danger of killing frosts has passed. The slopes of the lake basins are therefore peculiarly well adapted for raising fruit, and many orchards and vineyards are found there. The steep shores of Keuka Lake, especially, are covered with vineyards, as thick set as those of the Rhine.

The Finger Lakes comprise a group of 11 neighboring lakes, similar in form and topographic situation but differing widely in area and depth. Six of them may be classed as major lakes and five as minor, although the lakes in each group differ greatly from each other. The series offers for study lakes whose range of length is from 5 kilometers to more than 60 kilometers and whose range in depth is nearly tenfold. Thus the series extends from lakes of quite ordinary character to those which are inland lakes of the first order in every sense of that term. It is probable that there is no group of lakes in the world which offers to the limnologist such opportunities for working out the problems of his science.

Table I gives the general facts of the hydrography for the several lakes and for Green Lake, Wis., which is frequently compared with the New York lakes in the discussion of temperatures.

TABLE I.—HYDROGRAPHY OF THE NEW YORK LAKES.

Lakes.	Drainage area.		Elevation above sea.		Length.		Breadth.			Area.	
							Maximum.		Mean.		
	<i>Square kilo- meters.</i>	<i>Square miles.</i>	<i>Meters.</i>	<i>Feet.</i>	<i>Kilo- meters.</i>	<i>Miles.</i>	<i>Kilo- meters.</i>	<i>Miles.</i>	<i>Kilo- meters.</i>	<i>Square kilo- meters.</i>	<i>Squa- re miles.</i>
Canadice.....	31	12	333	1,092	5.1	3.2	0.62	0.39	0.51	2.6	1.0
Canandaigua.....	453	175	209	686	24.9	15.5	2.44	1.50	1.70	42.3	16.3
Cayuga.....	2,106	813	116	381	61.4	38.1	5.60	3.50	2.80	172.1	66.4
Conesus.....	231	89	249	818	12.6	7.8	1.34	.83	1.06	13.4	5.2
Hemlock.....	111	43	273	896	10.8	6.7	.80	.50	.70	7.2	2.8
Keuka.....	484	187	216	709	31.6	19.6	3.32	2.06	1.15	47.0	18.1
Otisco.....	88	34	239	784	8.7	5.4	1.22	.76	.89	7.6	2.9
Owasco.....	539	208	217	710	17.9	11.1	2.10	1.30	1.49	26.7	10.3
Seneca.....	1,831	707	135	444	56.6	35.1	5.20	3.25	3.10	175.4	67.7
Skaneateles.....	189	73	264	867	24.2	15.0	2.35	1.46	1.48	35.9	13.9
Green (Wis.).....	246	95	275	902	11.9	7.4	3.22	2.00	2.50	29.7	11.5

Lakes.	Depth.			Dm. Dmx.	Volume.		Mean slope.		Development.	
	Maximum.		Mean.						Shore.	Volume.
	<i>Meters.</i>	<i>Feet.</i>	<i>Meters.</i>		<i>Million cubic meters.</i>	<i>Million cubic feet.</i>	<i>Per cent.</i>	<i>° ' "</i>		
Canadice.....	25.4	83	16.4	0.65	42.6	1,503	6.2	3 33	2.05	1.04
Canandaigua.....	83.5	274	38.8	.40	1,640.1	57,897	7.0	4 0	2.48	1.30
Cayuga.....	132.6	435	54.5	.41	9,379.4	331,080	5.2	2 58	3.35	1.23
Conesus.....	18.0	59	.....	.....	.....	.....	.....	.....	.....	.....
Hemlock.....	27.5	90	.....	.....	.....	.....	.....	.....	.....	.....
Keuka.....	55.8	183	30.5	.55	1,433.7	50,610	7.8	4 28	4.58	1.64
Otisco.....	20.1	66	10.2	.51	77.8	2,746	2.3	1 21	2.04	1.52
Owasco.....	54.0	177	29.3	.54	780.7	27,578	4.4	2 31	2.27	1.63
Seneca.....	188.4	618	88.6	.47	15,539.5	548,544	9.0	5 08	2.74	1.41
Skaneateles.....	90.5	297	43.5	.48	1,562.8	55,151	8.4	4 48	2.45	1.44
Green (Wis.).....	72.2	237	33.1	.40	984.8	34,751	5.4	3 06	1.78	1.38

TABLE I.—HYDROGRAPHY OF THE NEW YORK LAKES—Continued.

Lakes.	$\frac{A}{2}$ at M.	Per cent of Dmx.	$\frac{V}{2}$ at M.	Per cent of Dmx.	Surveyed by—	Date.	Number of sound- ings.	Scale of original map.
Canadice.....	19.5	77	9.5	37	City of Rochester.	1909	283	1:2,400
Canandaigua.....	44.0	53	26.0	31	Cornell University.	1888-1890	395	1:40,000
Cayuga.....	47.0	33	40.0	30	do.....	1875-1878	397	1:60,000
Conesus.....					U. S. Geological Survey.	1904		1:62,500
Hemlock.....					do.....	1904		1:62,500
Keuka.....	32.0	58	18.0	32	Cornell University.	1884-1888	470	1:40,000
Otisco.....	12.5	62	6.6	33	do.....	1897	144	1:24,000
Owasco.....	33.0	61	18.0	33	do.....	1896-97	276	1:40,000
Seneca.....	88.0	47	57.0	30	do.....	1878-1883	405	1:60,000
Skaneateles.....	46.0	51	29.0	32	do.....	1893	572	1:30,000
Green (Wis.).....	32.0	44	23.0	32	Wisconsin Geological Survey.	1898	697	1:20,000

EXPLANATION OF TABLE I.

In table I the areas of drainage basins were taken from Rafter's Hydrology of New York, except Canadice Lake, whose basin was measured from United States Geological Survey maps, and Green Lake, which was measured from Wisconsin maps.

The drainage area of Seneca Lake includes that of Keuka Lake.

Elevations above sea were from the United States Geological Survey maps, except Green Lake. In this case the elevation is that found in Gannett's Dictionary of Altitudes in the United States, and refers to the railway station, which is somewhat below the level of the lake.

Length, depth, etc., were measured or computed from the maps named in the table.

The length of each lake was measured along its axis. That given for Keuka Lake is the length of the east arm and main lake; the west arm is 10.6 kilometers (6.6 miles) long. The maximum breadth of Keuka Lake is at the junction of the arms; elsewhere the maximum breadth is 1.48 kilometers (1.1 miles).

The mean breadth of the lakes was found by dividing the area by the length. The mean depth was found by dividing the volume by the area.

The depths given for Hemlock and Conesus Lakes are those found by the authors. The lakes have not been surveyed, but probably these numbers are near the maximum depth.

$\frac{Dm}{Dmx}$ is the ratio of the mean depth to the maximum depth.

The volume assigned to each lake in this table is the sum of the volumes of the several strata as given in the tables of detailed hydrography (p. 597). These are computed from the formula $v = h \frac{(A+B+\sqrt{AB})}{3}$, in which h is the contour interval, A and B are the areas of the bounding planes of the stratum.

The mean slope was computed according to the formula of Gravelius $S = \frac{H}{A} \frac{(\frac{1}{2}l_0 + l_1 + l_2 + \dots + l_{n-1} + \frac{1}{2}l_n)}{n}$, in which H is the depth of the lake, A its area, and l_0, l_1 , etc., the length of the successive contours.

The mean slope of the areas between the several contours in the detailed tables of hydrography was calculated from the formula $S = \frac{h(l_1 + l_2)}{a \left(\frac{l_1 + l_2}{2} \right)}$, in which h is the contour interval, a the area between the contours, and l_1, l_2 the length of the contours.

Shore development is the ratio of the perimeter of the lake to the circumference of a circle whose area equals that of the lake.

Volume development is the ratio of the volume of the lake to that of a cone whose base equals the area of the lake and whose height is the maximum depth of the lake. If the sides of the lake were vertical the volume development would be 3 or the volume would be that of a cylinder of equal base and altitude. The formula is $\frac{3Dm}{Dmx}$ and the numbers of this column are therefore three times those in the column $\frac{Dm}{Dmx}$. That part of the number which follows the decimal point is, in these lakes, the same as Peucker's figure for "mittlere Wöhlung."

$\frac{A}{2}$ at m. This column shows to the nearest meter or half meter the depth at which the area of the lake basin is reduced to one-half of that of the lake's surface.

$\frac{V}{2}$ at m. shows in like manner the depth of the plane which divides the volume of the lake into two equal parts.

The columns headed "per cent of Dmx" show the ratio of these depths to the maximum depth of the lakes.

See account of Otisco Lake (p. 542) for other statistics.

LAKES OF THE SENECA BASIN.

Seneca and Cayuga Lakes (pl. CXIII, CXIV).—These are the largest and deepest lakes of the group and closely resemble each other in surface dimensions. Seneca Lake, however, is nearly 56 meters deeper than Cayuga, the ratio of the maximum depths of the two lakes being 1: 1.42. The mean depth of Cayuga Lake is even less, being to that of Seneca in the ratio of 1: 1.63, and their volumes have about the same ratio. The map shows a large area of shoal water at the north end of Cayuga Lake, which is not found in Seneca Lake. The outlet of Cayuga Lake, also, passes at once into the extensive Montezuma marshes, another indication of the flat condition of the country at the north end of the lake.

The topography of the shores of these lakes is very similar. The country is relatively flat at the north end. (See fig. 2 as well as the plates.) The shores rise toward the south and for the southern half or two-thirds of their length, the lakes are bounded by a steep slope, often precipitous at the bottom, which reaches in places 100 meters or more in height. Above this steep slope there is for much of the way a more or less definitely marked shelf, and above this there is another rise to more considerable isolated heights. There are no high hills which crowd down toward the water as is the case in most of the other lakes. The lakes have the appearance of a broad, quiet river, with steep banks of nearly uniform height. Their scenery is therefore rather tame as compared with that of the other major lakes; but at the southern end of both lakes the entering streams have cut deep gorges which are famous for their beauty. The lateral tributaries of these lakes are larger than those of the smaller ones and points built out by them into the lakes are correspondingly larger. At the south end of each of these lakes there is a flat or delta built out into the water by the large streams which enter from the south.

The authorities which we have consulted give the area of Cayuga Lake as slightly larger than that of Seneca, but our very careful measurements, both from the Cornell maps and those of the United States Geological Survey, reverse this relation. The following table shows the details for each lake:

TABLE II.—AREAS OF CAYUGA AND SENECA LAKES.

Authority.	Area in square miles.	
	Cayuga.	Seneca.
Rafter ^a	66.8	66.0
Cornell maps.....	66.4	67.7
United States Geological Survey maps.....	66.0	66.3

^a Rafter, G. W.: Hydrology of the State of New York. New York State Museum Bulletin 85, 1905, p. 216.

The transparency of these lakes, as measured by Secchi's disk in 1910, was 5.1 meters for Cayuga Lake and 8.3 meters for Seneca.

These lakes are part of the canal system of New York, and their outlets are controlled by the works at the entrance of the canals into the lakes.

Our observations on Seneca Lake were made in the deep water off North Hector. In Cayuga Lake they were made off Sheldrake and King Ferry.

For the details of the hydrography, see p. 598.

Owasco Lake (pl. cxii).—Owasco Lake is the smallest of the six major lakes, having about 70 per cent of the length of Skaneateles and Canandaigua Lakes. Its mean breadth is, however, somewhat greater, so that its area is about 70 per cent of that of Skaneateles Lake, its neighbor to the east. It is also the shallowest lake (54 meters, 177 feet), although Keuka Lake exceeds it by less than 2 meters in maximum depth, and a little more than 1 meter in mean depth. It has the form typical of these lakes—a broader, rather shallow northern part extending into the lower country, and a narrow south part with steep sides. The valley, however, lies in that depression of the highland which includes the north parts of Seneca and Cayuga Lakes. Its banks are, therefore, on the whole, lower than those of any of the other lakes, although of the same general character. The valley extends about 30 kilometers (18 miles) to the south, and with steeper slopes than any of those found immediately adjacent to the water. Near the lake the steep slope at the bottom never exceeds 100 meters, and is usually much less, and above this the slopes are gradual and do not rise to elevations much exceeding 200 meters above the lake. The lake itself is about 100 meters above Cayuga Lake, its neighbor to the west, and less than half as much below Skaneateles Lake.

The outlet is controlled by a dam, and the lake is the source of water supply for the city of Auburn, which lies at its north end. The south end of the lake is somewhat silted up by alluvium brought down by the inlet, as is shown by the form of the 25-foot contour, and the valley is probably deeply filled with loose materials.

In a report made in 1909 to the city of Auburn, Mr. G. P. Whipple computed the volume of Owasco Lake as equal to about 200,000,000,000 gallons, which would equal about 2,670,000,000 cubic feet. This computation is based on the same survey as ours, and is somewhat smaller than our estimate. (See table 1.) Whipple's diagram, however shows the volume of the lake as slightly larger than our figures.

Our observations in 1910 were made off Wyckoff, and temperatures were taken there in the winters of 1911 and 1912. Four series of temperatures were taken in 1911, the first near Rice Point at the south, and the last near the northern limit of the 100-foot contour.

For the details of the hydrography, see p. 598.

Keuka Lake (pl. cxv).—Keuka Lake, which drains into Seneca Lake, lies about 80 meters above it. The stream which carries its water flows through a narrow post-glacial gorge and empties into Seneca Lake near Dresden.

Keuka is the largest of the lakes after Cayuga and Seneca, and it is also the narrowest. It is the only lake whose outline is irregular. Its west arm, though the shorter, is the deeper, the 150-foot contour extending close to the northern end. The lake lies, as a whole, farther to the south than does any other of the district, and both branches of the basin are narrow to the extreme north end, since the valley does not widen out on the northern face of the plateau. It is one of the shallowest of the six major lakes, being less than 2 meters deeper than Owasco. The under-water slopes of

the basin are very steep, as are also those above water; and these steep slopes begin close to the northern end of the lake and extend through its length. Bluff Point, which divides the two arms of the lake, is one of the finest hills to be found adjacent to the lakes, and has been most characteristically shaped by glacial action.

The waters of Little Lake, which is shown on the map, drain into the Susquehanna River, and thus reach Chesapeake Bay, while those of Keuka Lake ultimately reach the Gulf of St. Lawrence.

Observations were made on Keuka Lake in the deepest water off Grove Springs.

For the details of the hydrography, see p. 598.

Canandaigua Lake (pl. cxvi).—Canandaigua Lake repeats the typical form of the Finger Lakes—a basin, relatively broad and shallow at the north end, with flat low-lying shores. To the south the hills rise and steepen and come down close to the lake. The hills on the east side rise with a steep slope almost to their summits, South Hill showing a rise of nearly 400 meters in 1 kilometer, while other slopes are nearly as steep for shorter distances. No lake has so many high hills adjacent to it. Burr and South Hills lie to the east, and on the west are Powell and Stid Hills. Between these is Bristol Hill, which reaches a height of about 500 meters (1,604 feet) above the lake. Its summit is just to the west of the limits of the map, due west from Lapham Point. Between these hills are deep valleys, of which Vine Valley on the east side is the most conspicuous. These high hills, with their valleys, make the scenery of Canandaigua Lake more diversified than that of any other Finger Lake. No single view, indeed, is finer than that of Bluff Point from Keuka Lake, but in variety of scenery Canandaigua excels.

The transparency of the lake in 1910 was 3.7 meters, the lowest found in the major lakes.

Observations on gas and plankton were made in the deepest water and not far from Grange Landing. In both 1911 and 1912 four series of temperatures were taken, of which the southern was near Cooks Point, and the northern near Hope Point.

For the details of the hydrography, see page 597.

Skaneateles Lake (pl. cx1).—Skaneateles Lake is the easternmost of the six major lakes and is almost a replica of Canandaigua, the westernmost. Its length is almost the same, its breadth slightly less, and its area correspondingly smaller. Its depth, both mean and maximum, is greater, in spite of which the shores to the south are not so high as those of Canandaigua, nor are there the deep lateral valleys that diversify the steep walls of the latter basin. The highest and steepest slopes are reached only at the extreme south end of the lake and extend up the valley beyond the water. Here on the west side is found a slope about 250 meters high with a gradient of about 1:3. This is, as usual, exceeded by the under-water slopes, which reach near Carpenters Point a maximum of 1:1.5 for a height of 60 meters.

The transparency of the lake in 1910 was 10.3 meters, by far the greatest found. This had no apparent effect on the distribution of temperature.

Skaneateles Lake serves as a reservoir for part of the canal system of New York, and its outlet is controlled by a dam, which raises the water perhaps about 2.5 meters

(8 feet) above its natural low level of 70 years ago. The water of this lake, with that from Otisco Lake, is also used for the water supply of the city of Syracuse, which lies some 27 kilometers to the northeast.

Our observations in 1910 were made off Carpenters Point. The later temperature observations were taken off Mandana.

For the details of the hydrography, see page 599.

Otisco Lake (pl. CXI).—Otisco Lake is quite similar in situation and form to the six major lakes, but is wholly different in area, depth, and biological character. The lake is used as a source of water supply for the city of Syracuse, which lies about 27 kilometers to the northeast. The height of the water is controlled by a dam, which may raise the water 3 meters or more above its original level. This dam is placed some 1.5 kilometers below the original outlet and has thus caused a shallow extension of the lake at the south end. The sides of the original lake are steep, and the increase in height of the water adds little to its breadth. At the south end of the lake the floor of the valley slopes very gradually and here the dam has caused a broad, shallow expanse which varies greatly in area with the rise and fall of the water as it is drawn upon for the use of the city.

Across this shallow expanse and close to the original south end of the lake there runs a causeway pierced only by a narrow opening. There is thus a considerable area of shallow water which is practically separated from the main body of the lake.

In the general table of the lakes the statistics for Otisco Lake are based on the Cornell survey and include the entire lake. The level of the water shown by this survey was not correlated with the level of the crest of the dam, or if such measurements were made (as they probably were) the records have disappeared. The water was probably about 1 meter below the spillway at the time the soundings were taken. They therefore do not represent the maximum possible depth of the lake, but are probably quite as great as the ordinary depth.

For all purposes of limnology the southern extension of the lake beyond the causeway has no significance, however valuable it may be as a storage for water supply. For the purposes of our discussion, the dimensions of the lake must be recalculated, including that part of the lake which lies between the dam and the causeway. The results are as follows: Length, 7.33 kilometers; breadth, maximum, 1.22 kilometers; mean, 0.93 kilometers; area, 6.84 square kilometers; depth, maximum, 20.1 meters; mean, 11.2 meters; volume, 76,440,000 cubic meters; shore development, 1.76; volume development, 1.64; mean slope, 2.41 per cent, $1^{\circ} 23'$. These measurements are employed in the table of hydrography, page 597.

Otisco Lake occupies only a small part of its valley, which extends far beyond the lake both to the north and the south. Its steepest slopes begin at about the same point as do those of the Skaneateles valley, and since the lake is little more than one-third as long, they lie wholly to the south of the water. In general they are more broken and diversified than are those of the other eastern lakes. There is hardly a view in this picturesque and beautiful region finer than is that which the Otisco Valley

offers as the traveler from Skaneateles first enters it from the south, high up on the slopes of its western side.

Otisco Lake was visited only once. The work was done off Amber, in the deepest water. The lake abounds in plankton, as is indicated by the absence of oxygen and plankton in the deeper water. Its transparency in 1910 was 3 meters, the least shown by any of the lakes, but not much less than several of them.

For the table of hydrographic details, see page 597.

LAKES OF THE GENESEE BASIN.

Honeoye, Canadice, Hemlock, and Conesus Lakes (fig. 3).—These four small lakes lie to the west of Canandaigua Lake (fig. 1), in narrow valleys, at an average altitude decidedly greater than that of the lakes of the Seneca Basin (fig. 2). One of them, Honeoye Lake, was not visited by us. The lake is shallow, as is shown by the large deltas which have been built out into it by the small streams along its sides.

Conesus, the westernmost lake, lies farthest to the north, and therefore comes nearest to the mouth of its valley. The valley is shallow and has gradual slopes, not exceeding 1:5 for a height of 100 meters (over 300 feet). The highest hills adjacent to the lake do not reach a height greater than 160 meters (530 feet) above its surface. The most interesting topographic feature of the lake is the fact that near its center two streams, entering opposite each other, have built out large deltas, which have nearly divided the lake. The water is shallow; we found no depth greater than 18 meters. We made soundings along the center of the southern half of the lake, and the greatest depth of the lake is probably little, if at all, greater than that found by us. The transparency of the water was 6.3 meters, which was exceeded only by Skaneateles and Seneca Lakes. The oxygen and plankton of the lake show the regular characters that belong to a shallow lake.

Canadice and Hemlock Lakes lie close together in the center of this group. They are separated by the height of Bald Hill, which lies between them, much as Bluff Point lies between the two arms of Keuka Lake, and which has a form quite similar to that of Bluff Point (pl. cxv). It rises, however, to a greater height, since its summit is nearly 600 meters (1,850 feet) above the sea, and it rises more than 230 meters (760 feet) above Canadice Lake and about 290 meters (950 feet) above Hemlock Lake. The water of these two lakes furnishes part of the supply for the city of Rochester, which lies about 45 kilometers (28 miles) to the north.

Hemlock Lake is long, narrow, nearly straight, and is singularly uniform in breadth. The walls of the valley are steep, the steepest slopes rising 300 meters or more in 1 kilometer. None of the slopes are precipitous, but many of them are about as steep as is possible for a wooded slope to lie. Marrowback Hill, on the west of the lake, is as steep as Bald Hill on the east and reaches a height some 30 meters (100 feet) greater. The sides of both these hills are uniform and are unbroken by valleys or projections. Toward the north end of the lake are a few small streamlets whose valleys are almost invisible, and even these are not found along the southern two-thirds

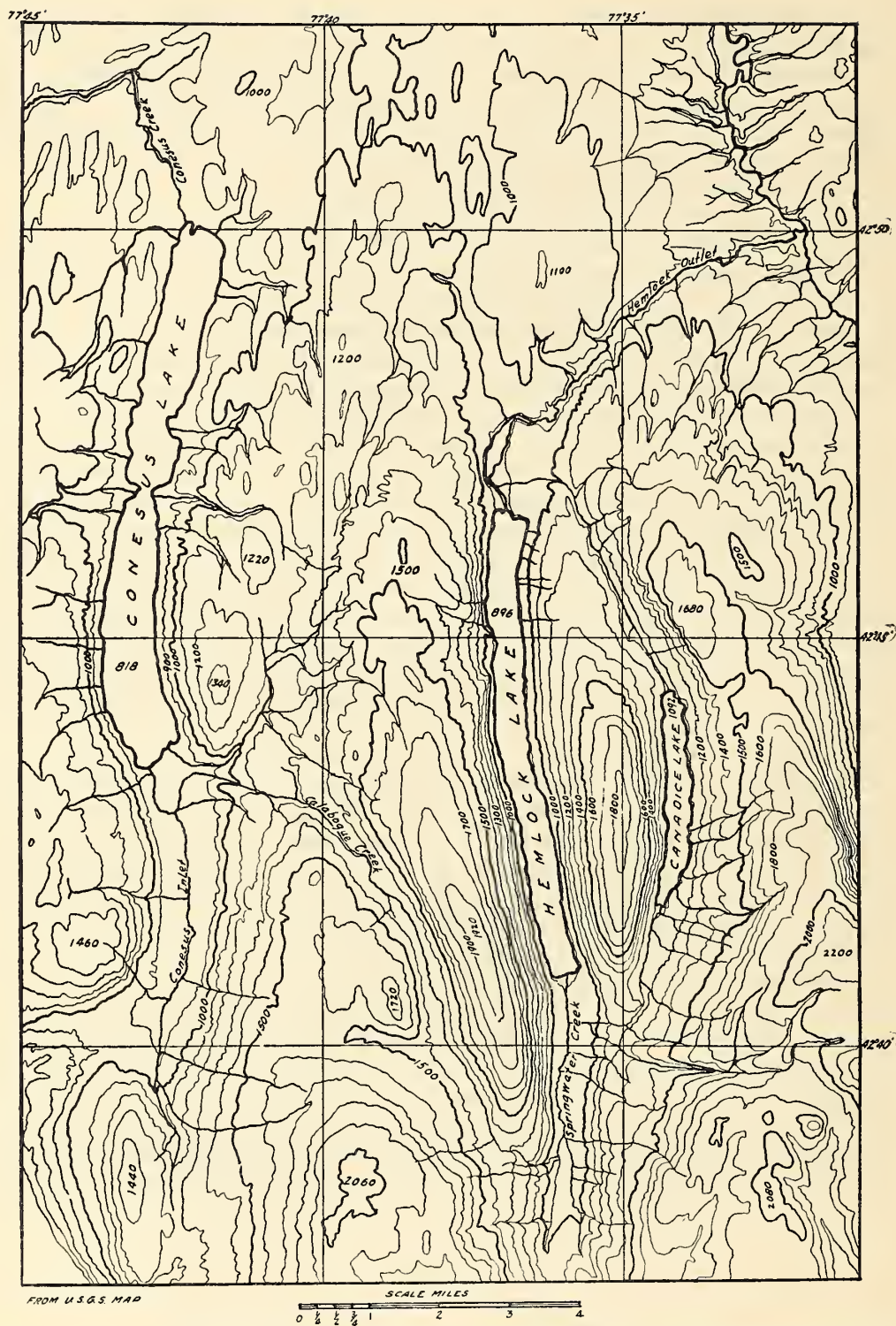


FIG. 3.—Contour map of western lakes of the Genesee Basin from topographic sheets of the United States Geological Survey. Scale about 1:155,000; 1 inch=2.5 miles; 1 cm.=1.6 km. Contour interval 100 feet. Elevations in feet above the sea level. Numbers on tops of hills indicate highest contour shown on United States Geological Survey map. The height between Canadice and Hemlock Lakes is Bald Hill; that west of Hemlock Lake is Marrowback Hill.

of the lake. There are, therefore, no deltas built into the lake, but the steep wall of the valley rises immediately from the water on both sides of the lake.

The outlet of Hemlock Lake is controlled by a dam, which may raise the water to a height of about 1.6 meters (5 feet) above its natural level. No hydrographic survey has been made of the lake. This is the more regrettable since the form and topography of the lake adapt it admirably to the study of the temperature seiche. Not only is the lake straight and of uniform breadth and depth, but the shape and depth of the valley are such that all winds that affect the water must blow parallel to the long axis of the lake.

The maximum depth of the lake as found by us was 27.5 meters (90 feet), and this was said by the officials of the Rochester water department to be the deepest water of the lake. The observations on Hemlock Lake were made near the middle of its length.

The transparency in 1910 was 4.7 meters.

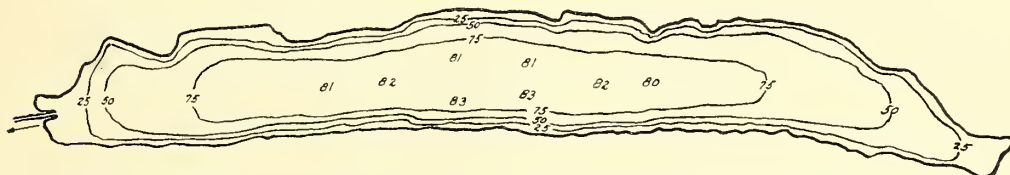


FIG. 4.—Hydrographic map of Canadice Lake. From survey by city of Rochester department of water supply. Contour interval, 25 feet. Scale, about 1: 64,000. Note the steep sides and flat bottom of the lake. The outlet of the lake is at the north end.

Canadice Lake (fig. 4) is the smallest of the lakes which we visited and the only lake of the Genesee Basin which has had a hydrographic survey. This was done with great care by the department of water supply of the city of Rochester, whose officials were so kind as to place their maps at our disposal.

The valley of Canadice Lake is a simple trough, with smooth steep walls, almost exactly like the valley of Hemlock Lake, though the eastern slopes of Canadice Valley carry somewhat larger streams and have cut somewhat deeper into its sides. The slopes under water are even steeper than those above it and the ratio between the maximum and the mean depth of the lake (see table 1) is considerably greater than for any other lake. More than three-fourths of the maximum depth must be passed before the plane is reached whose area is one-half that of the surface. In correspondence with this relatively great depth and volume Canadice Lake shows a biological character more resembling that of the larger lakes than does any other of the smaller lakes. It carries a good deal of oxygen to the bottom. The temperature of the deep water is low in spite of the fact that its total gains of heat are higher than would be expected from its area.

The lake was visited once and observations were made near the north end. The transparency of the lake was 4 meters.

For the details of the hydrography of the lake, see page 597.

TEMPERATURES.

GENERAL OBSERVATIONS.

Temperature observations were made in these lakes on the following dates:

Lake.	Date of observations.
Canadice.....	Aug. 24, 1910.
Canandaigua.....	Aug. 20, 1910; Sept. 4, 1911.
Cayuga.....	Aug. 11, 1910; Feb. 13, Sept. 2, 1911.
Conesus.....	Aug. 25, 1910.
Hemlock.....	Aug. 23, 1910.
Keuka.....	Aug. 18, 1910; Sept. 5, 1911.
Otisco.....	Aug. 16, 1910.
Owasco.....	Aug. 13, 1910; Feb. 11, Sept. 3, 1911; Mar. 1, Sept. 13, 1912. ^a
Seneca.....	Aug. 2, 3, 4, 7, 9, 1910; Feb. 10, Sept. 1, 1911.
Skaneateles.....	Aug. 15, 1910; Feb. 11, Sept. 3, 1911; Mar. 7, Oct. 15, 1912. ^a

The details of the observations are given in the tables of the appendix (p. 601). It will be seen that in all of the lakes temperatures were taken in August, 1910, and in four of the lakes series of temperatures were taken only at that time. Two other lakes were visited also in early September, 1911. Four others were visited in both summers and in February, 1911, and two of these also in March, 1912, and in the fall of that year. The attempt was made to secure series of temperatures which would show approximately the maximum summer temperature of the water, and in the case of those visited in the winter, the minimum temperature also. The most important conclusions to be drawn from the observations, as will be shown later, concern the annual heat budget of the lakes and the distribution of the heat in summer.

The study of the New York lakes was made in order to test in larger bodies of water the principles of lake temperatures established for the inland lakes of Wisconsin. Since the phenomena of the Finger Lakes exactly conform to these principles, we have not hesitated to use them as illustrations of these laws, though we should not have deduced the laws from them alone. The full discussion of these underlying principles belongs to the report on lakes of Wisconsin now under preparation, but several of them are briefly discussed in connection with this report.

The following principles are therefore assumed as demonstrated for lakes in the general climatic and topographic situation of the Finger Lakes. It is not asserted that they hold for lakes situated under other conditions.

1. Every deeper lake has an equithermal period of several weeks in summer, covering as a maximum August and parts of late July and early September, during which the daily gains and losses of heat nearly balance, when the mean temperature of the lake is substantially constant, and when the epilimnion has a nearly constant thickness. A series of observations taken on one day during this period gives a good idea of the general temperature condition of the lake during the whole period.

^a The observations of 1912 were made by Mr. J. W. Ackermann, superintendent of water works, Auburn, whose kind assistance is herewith acknowledged.

2. This condition recurs annually, unless under extraordinary conditions of weather, and the annual differences are not great enough to invalidate or seriously weaken general conclusions based on a single year.

3. A series of temperature observations taken in summer under good conditions of weather, and near the center of oscillation of a lake of regular form, gives a fair idea of the mean temperature of the water of the lake.

4. In lakes of this type, all heat gained which is above 4° and which is found below a depth of 5 meters, has been conveyed there by mechanical agencies; by currents due, directly or indirectly, to wind. Such heat may be called wind-distributed heat. The same is true of most of the heat found between the depth of 1 meter and 5 meters. There is as yet no clear evidence that thermal convection currents aid appreciably in carrying heat downward.

5. The thickness of the epilimnion in lakes of different size and otherwise comparable is a fair measure of the relative efficiency of the wind in distributing heat.

SUMMER TEMPERATURES.

As a result of the normal conditions of weather acting on the lake, it divides in summer into three well-known thermal regions.

1. The epilimnion, a stratum in which the temperature is nearly uniform. The surface is usually the warmest part of the stratum. Under summer conditions the fall of temperature in this region varies from a small fraction of a degree to several degrees. The amount varies chiefly with the temperature of the surface and is therefore subject to diurnal variation. It is greatest in the afternoon of a hot, calm day; least in the early morning, when the surface may be cooler than the stratum immediately below it.

2. The thermocline, the stratum of rapid cooling, whose limits are somewhat arbitrarily fixed as those of the region in which the fall of temperature equals or exceeds 1 degree per meter. Its upper limit is usually fairly definite, but below it grades off into the third region and its lower limit is often somewhat arbitrary. From 60 to 70 per cent, or even more, of the fall in temperature is usually found here. The thermocline is subject to variation in thickness under the action of wind and of oscillations due to temperature seiches. At the center of the lake where these influences are least felt, it is still subject to oscillations of considerable amount. These may cause an increase or decrease of the thickness of the thermocline, and at its bottom isotherms may be drawn in or excluded by its extension or contraction.

3. The hypolimnion, the region below the thermocline and extending to the bottom of the lake. In this region the temperature falls slowly, the temperature curve soon approaching a straight line. The amount of fall in this region varies greatly according to the conditions of the spring warming. It may be less than 3° , even in a layer more than 60 meters thick, or it may be as much as 6° . It may be as little as 11 per cent of the total fall in temperature or it may be nearly 40 per cent.

TABLE III.—SUMMER TEMPERATURES OF THE NEW YORK LAKES.

Lakes.	Year.	Depth.	Temperature.			Epilimnion.			
			Surface.	Bottom.	Fall of temperature.	Thick-ness.	Fall of temperature.	Per cent of total fall.	Fall per meter.
		<i>Meters.</i>	<i>°C.</i>	<i>°C.</i>	<i>°C.</i>	<i>Meters.</i>	<i>°C.</i>		<i>°C.</i>
Canadice.....	1910	25.4	22.2	8.0	14.2	7	0.4	2.8	0.06
Canandaigua.....	1910	85.5	21.7	5.4	16.3	12	2.0	12.2	.17
Do.....	1911		20.7	4.3	16.4	12	2.4	14.6	.20
Cayuga.....	1910	132.6	19.8	4.4	15.4	15	.6	3.0	.04
Do.....	1911		20.0	4.1	15.9	16	1.4	8.8	.09
Conesus.....	1910	18.0	21.8	12.5	9.3	8	.4	4.3	.05
Hemlock.....	1910	27.3	22.0	9.3	12.7	8	.3	2.4	.04
Keuka.....	1910	55.8	21.2	6.4	14.8	9	1.9	12.8	.21
Do.....	1911		20.6	4.8	15.8	11	1.1	7.0	.10
Otisco.....	1910	20.1	23.0	12.0	11.0	7	1.0	9.1	.14
Owasco.....	1910	54.0	21.5	7.0	14.5	12	2.0	13.8	.17
Do.....	1911		19.8	5.3	14.5	12	.3	2.7	.02
Do.....	1912		19.6	7.3	12.3	15	1.4	11.4	.93
Seneca.....	1910	188.4	20.0	4.2	15.8	12	2.0	12.7	.17
Do.....	1911		20.0	4.0	16.0	15	1.6	10.0	.11
Skaneateles.....	1910	90.5	22.7	5.4	17.3	9	3.7	21.4	.41
Do.....	1911		19.6	4.4	15.2	16	.8	5.3	.05
Green (Wis.).....	1910	72.0	22.5	5.3	17.2	11	2.0	11.6	.18
Do.....	1911		20.5	5.8	14.3	14	1.0	7.0	.71
Do.....	1912		21.7	6.3	15.4	10	1.2	7.8	.12

Lakes.	Year.	Thermocline.					Hypolimnion.			
		Thick-ness.	Fall of temperature.	Per cent of total fall.	Fall per meter.	Temperature at bottom.	Thick-ness.	Fall of temperature.	Per cent of total fall.	Fall per meter.
		<i>Meters.</i>	<i>°C.</i>		<i>°C.</i>	<i>°C.</i>	<i>Meters.</i>	<i>°C.</i>		<i>°C.</i>
Canadice.....	1910	5	10.6	74.7	2.12	11.2	13.4	3.2	22.6	0.24
Canandaigua.....	1910	8	11.5	70.6	1.44	8.2	63.5	2.8	17.2	.044
Do.....	1911	8	10.6	64.7	1.32	7.7	63.5	3.4	20.7	.054
Cayuga.....	1910	7	9.4	61.0	1.34	9.8	110.6	5.4	35.1	.05
Do.....	1911	5	9.3	58.5	1.86	9.2	111.6	5.2	32.7	.046
Conesus.....	1910	4	6.8	73.1	1.70	14.6	6.0	2.1	22.6	.35
Hemlock.....	1910	6	9.3	73.2	1.55	12.4	13.3	3.1	34.4	.23
Kenka.....	1910	6	9.6	64.0	1.60	9.7	40.8	3.3	22.3	.081
Do.....	1911	7	12.4	78.5	1.77	7.1	37.8	2.3	14.5	.061
Otisco.....	1910	5	8.5	77.3	1.70	13.5	8.1	1.5	13.6	.19
Owasco.....	1910	8	8.7	60.0	1.09	9.8	34.0	3.8	36.2	.11
Do.....	1911	8	10.2	70.4	1.28	9.3	34.0	4.0	27.5	.12
Do.....	1912	5	7.3	59.3	1.46	11.9	34.0	3.6	20.3	.11
Seneca.....	1910	8	7.8	49.4	.98	10.2	168.4	6.0	38.0	.036
Do.....	1911	7	10.9	68.1	1.56	7.5	166.4	3.5	21.0	.021
Skaneateles.....	1910	9	9.7	56.1	1.08	9.3	72.5	3.9	22.5	.054
Do.....	1911	6	9.3	61.2	1.55	9.6	68.5	5.1	33.5	.074
Green (Wis.).....	1910	7	12.3	71.5	1.76	8.2	54.0	2.9	16.0	.054
Do.....	1911	6	10.8	75.5	1.80	8.7	52.0	2.5	17.5	.047
Do.....	1912	5	8.1	52.6	1.62	12.4	57.0	6.1	39.6	.11

Figures 5 and 6 give the temperature curves of the six major lakes to the depth of 50 meters for the summers of 1910 and 1911. All of them show the typical midsummer temperature curve of an inland lake. They show a striking resemblance to each other in form and there is less difference in the relative thickness of epilimnion and thermocline than might be expected. Keuka Lake departs in both years most widely from the others, and reasons can be assigned for this fact, but any of the other lakes might conceivably occupy any place in the set of curves. This close resemblance is an indication of the fact that the various lakes have absorbed nearly equal amounts of heat. The same fact is also indicated by the lower parts of the curve, which indicate in general

warmer water for the shallower lakes. Keuka and Owasco Lakes, which hardly exceed 50 meters in depth, are the warmest at the bottom in 1910. Skaneateles Lake accompanies them in 1911, but the observations were not at the best place. (See p. 540.) Seneca and Cayuga, the deepest of the lakes, are the coldest, and are both at about the

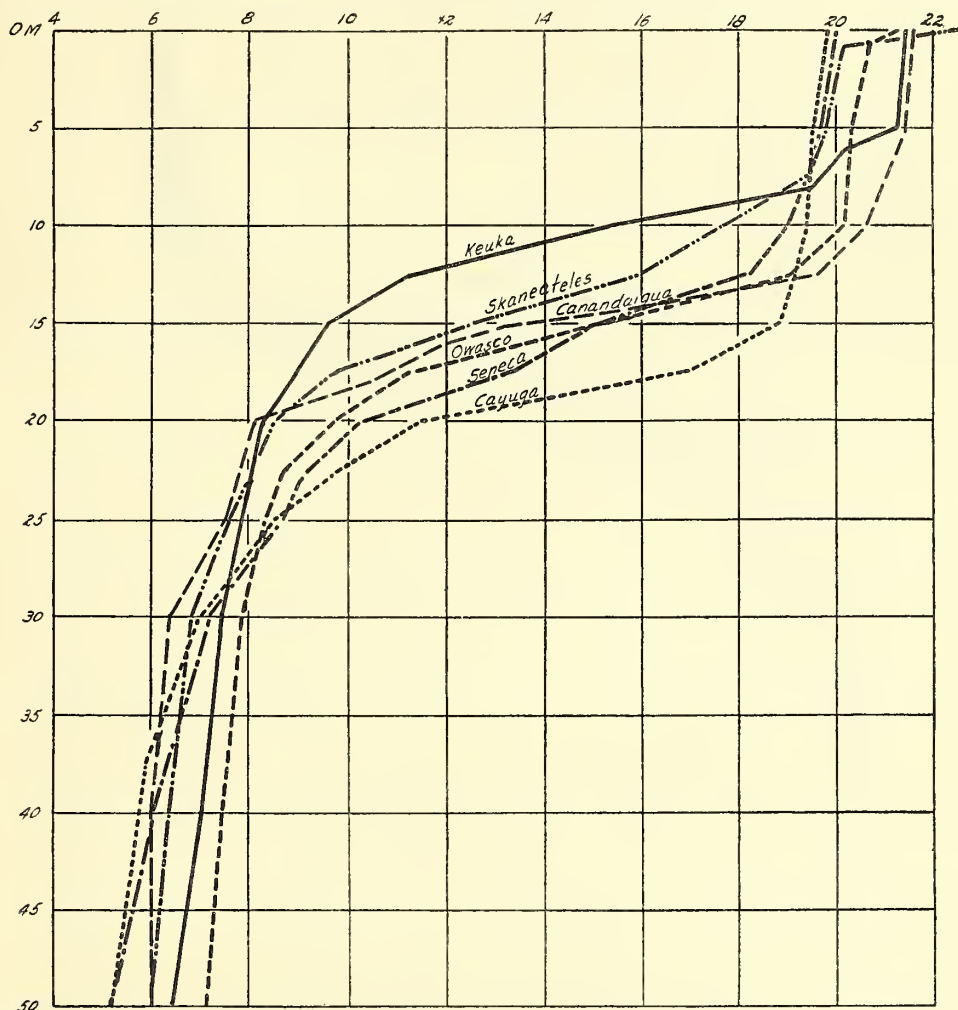


FIG. 5.—Temperature curves of the six major Finger Lakes in 1910, shown to the depth of 50 meters. One vertical space represents 5 meters in depth; one horizontal space represents 2° C. See p. 548.

same temperature. These facts of bottom temperatures should be expected on general principles, as stated by Wedderburn.^a But the resemblance of the upper part of the curves is greater than would be anticipated.

^a Wedderburn, E. M.: Temperatures of Scottish lochs. Bathymetrical survey of the fresh-water lochs of Scotland, vol. 1, p. 97. Edinburgh, 1910.

Surface and epilimnion.—The table shows that the surface temperatures of these lakes varied about as would be expected considering their size and depth. During the time necessary to visit the lakes no considerable depression of temperature occurred which would cool the surface, so that the observations in the different lakes are comparable.

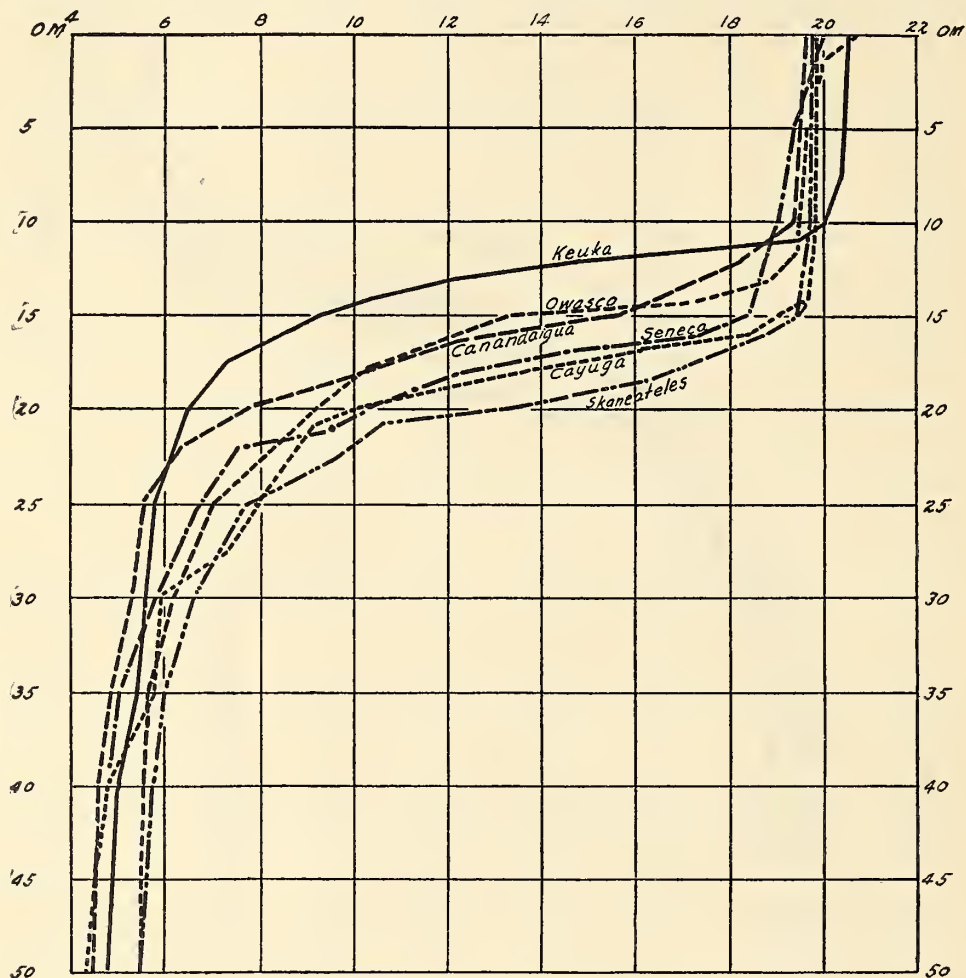


FIG. 6.—Temperature curves of the six major Finger Lakes in 1911, shown to the depth of 50 meters. One vertical space represents 5 meters in depth; one horizontal space represents 2°C . See p. 548.

During 1910 the weather was without a cold period until after the first week in September, and in 1911 the first weeks of September were among the warmest of the season, and no marked depression of temperature occurred during August. There is therefore every reason to believe that the series represents the approximate maximum of the season, a maximum which would be surpassed during a succession of calm, hot days, but which

would not be exceeded in ordinary summer weather. The surface temperature of steep-sided lakes is necessarily lower than that of lakes with shallow margins, and that of the smaller lakes is, for similar reasons, usually higher than that of the larger.

If we consider the six main lakes only, the mean thickness of the epilimnion in 1910 was 11.5 meters (9 to 15 meters); in 1911 it was 13.7 meters (11 to 16 meters). In twelve series of temperatures taken in six lakes in 1910 and 1911, the mean thickness was 12.6 meters. No constant difference due to area or depth appears in the list. Keuka Lake had the thinnest epilimnion in both years, a condition undoubtedly due to the fact that it is narrower than any of the other lakes, and that its shores are on the whole higher and steeper than the others. The wind has therefore less opportunity to distribute the warm surface water. The effect of the same cause is found also in the fact that the annual gains of heat in Keuka Lake are the smallest of the six, as will be shown later, and also in its relatively low bottom temperature. Cayuga Lake indicates rather doubtfully a tendency toward an epilimnion a little thicker than the others. I believe this will be found to be the fact when a sufficient number of observations have been made. There is nothing conclusive, however, in the observations given, as they are quite within the range of accidental variation.

I have added to the table of New York lakes the facts for Green Lake, Wisconsin, which lies in a climate not essentially different from that of central New York. These show that the epilimnion in these years had a thickness almost exactly the same as those of the New York lakes. Green Lake has a length of about 11.4 kilometers while those in New York vary from about 18 kilometers to more than 60 kilometers. Their mean breadth is of the same order of magnitude as that of Green Lake, and is therefore relatively less. This, however, makes little difference in the effect of wind in favor of Green Lake, since the long axis of Green Lake lies across the prevailing direction of the wind, or at least obliquely to it, while the New York lakes are much more nearly parallel to it. This fact, coupled with the greater length of the lakes, should make the influence of the wind as great for any of the lakes and much greater for some of them. In Seneca Lake, for instance, the currents induced by wind are often so strong that even when no wind is blowing a deep-sea thermometer will not sink perpendicularly unless extra weight is attached to the line. This condition never occurs in the Wisconsin lakes.

It appears, therefore, that 12 to 15 meters is about the maximum thickness which can be expected in the epilimnion of an inland lake before the temperature of the water begins to decline. Such a statement applies only to lakes which lie under the topographic and climatic conditions of the lakes discussed. Variations are found and the thickness must be measured by meters and not by centimeters; but in any ordinary season the observer may confidently expect to find the thermocline about where he found it in previous years. It may be a little higher or lower, but the thickness of the epilimnion in the same lake will always be of the same order of magnitude.

Thermocline.—We understand by the thermocline that thermal region of the lake lying immediately below the epilimnion, in which the temperature falls rapidly. This

word was proposed by the senior author of this paper in 1897 as an equivalent for Richter's term "sprungschicht," and was so defined. In this sense it has been included in the New Oxford Dictionary and also in the Century Dictionary. In 1912 Wesenberg-Lund^a redefined the word so as to restrict it to the meter of maximum fall of temperature, retaining the word "sprungschicht" for the larger stratum. We see no sufficient reason for this change, which would force a writer in English to invent a new equivalent for "sprungschicht" or else employ some long paraphrase for that term, such as Wedderburn's "discontinuity layer." We therefore retain the term "thermocline" in its original sense, in which it has been adopted by English dictionaries.

The terms "epilimnion," "thermocline," and "hypolimnion" are derived from that thermal condition of the lake which extends from early midsummer to the beginning of the homothermal period in autumn. Like all conditions that arise as a result of growth, this one comes on gradually, and its beginnings are not easy to define. In this paper the situation is treated and discussed as it appears in late summer during the equithermal period. Table II shows that the thermocline in the six major lakes (or seven with the addition of Green Lake, Wis.) was from 5 to 9 meters thick; that the fall of temperature in it was from 7.3° to 12.3°; and that this fall represented from about 40 per cent to nearly 80 per cent of the difference of temperature between the surface and the bottom of the lake. In the smaller lakes it is 4 to 6 meters thick, but contains a decline of temperature nearly as great as that of the larger lakes and one which represents a higher average percentage of the total fall.

These figures have little significance in their details; since, as already stated, the thermocline is subject to constant alterations of thickness due to the oscillations of the water of the lakes. These changes may continually and rapidly alter the average rate of fall of temperature, and the total number of degrees included in the thermocline; the position of the meter of maximum descent of temperature, and the amount of fall included in it. The figures therefore represent in their range of variation about what might be expected in lakes of this size under average conditions of summer weather. Any of the major lakes might, under suitable conditions, show a thermocline like that of any one on the list.

The general result, however, shows more than the single observation. The thermocline lies deeper in the larger lakes than in the smaller, and on the average is over 1.5 meters thicker. This region represents the stratum in which the effects of the direct wind circulation die out, just as the epilimnion is the stratum in which a direct wind circulation is made possible by the cooling effect of night and of cool periods. It might be thought that in the larger lakes the greater influence of the winds would make the descent of temperature in the thermocline more gradual. This is true to a limited extent, as is best seen in the thermocline of Seneca Lake. It is more evident when large lakes are compared with very small ones. In general, however, the greater effect of wind in the larger lakes is rather to increase the thickness of the epilimnion than to

^a Brönsted, J. N., and Wesenberg-Lund, C.: Chemisch-physikalische Untersuchungen der dänischen Gewässer. Internationale Revue der gesamten Hydrobiologie und Hydrographie, bd. IV, 1911, Biologisches Supplement, sr. II, p. 262. Leipzig, 1911-12.

modify the character of the thermocline. This means that as soon as the thermal resistance to mixture is strongly felt the work of the wind is rapidly cut off, more slowly in the larger lake, but not at all in proportion to its increased size.

The last column in table III under the head of thermocline gives the temperature at the bottom of that region. It will be noted that these temperatures differ and show no relation to the temperature of the ground water.

Hypolimnion.—In the hypolimnion the temperature falls at first rapidly; then more slowly, the curve approaching a straight line. The lower part of the very deep lakes may have a temperature nearly, or quite, the same through a considerable thickness of water. The division between thermocline and hypolimnion is not very definitely marked and is variable. The division of heat between these two regions is correspondingly uncertain.

If similar climatic conditions are assumed, the temperature at the bottom of the lake varies with two factors, the size and the depth of the lake. On the size of the lake depends the efficiency of the wind until a certain area has been reached. This we have placed at the length of about 10 kilometers for lakes with a mean depth of 30 meters or more. Six of the Finger Lakes reach or exceed this area and depth, and therefore have the maximum bottom temperatures possible under the conditions of the season of observation. Two of the lakes, Canadice and Otisco, are both too small and too shallow to permit the wind to have the maximum effect; and two others, Conesus and Hemlock, are too shallow.

In the six larger lakes the bottom temperature in general follows the depth of the lakes, the shallower lakes having a higher temperature. In 1910 it varied from 7.0° in Owasco Lake to 4.2° in Seneca Lake; and in 1911 from 5.3° to slightly above 4° in the same lakes. Owasco and Keuka Lakes have nearly the same maximum depth, but the bottom temperature of Keuka Lake is decidedly lower than that of Owasco in spite of its much greater length. This is due to the same cause that produced the thin epilimnion in Keuka Lake (p. 551). Skaneateles and Canandaigua Lakes, which have substantially the same length and depth, have also closely similar bottom temperatures, while the two larger and deeper lakes, Cayuga and Seneca, follow in the order of their depth.

In 1911 all of the bottom temperatures were lower than in 1910. The difference was almost the same in Owasco and Keuka Lakes (1.7° and 1.6° , respectively), and the same is true for Skaneateles and Canandaigua Lakes (1.0° and 1.1° , respectively). Cayuga Lake was about 0.3° lower in 1911 and Seneca Lake was between 0.1° and 0.2° lower. In 1911 the temperature of Seneca Lake below 100 meters was very little above 4° . The mercury was slightly above the mark, but the reading would be less than 4.05° . Our deep-sea thermometer was not provided with an accessory thermometer for giving the temperature of the mercury at the time of reading and so making correction for the expansion of the mercury in the tube. It is therefore not improbable that the true temperature of the bottom water of Seneca Lake in 1911 was slightly below 4.0° .

The widely different temperatures of the hypolimnion in 1910 and 1911 undoubtedly reflect the difference of the weather in the spring of those years, though there are no

direct observations to support the conclusion. In 1910 March and April were warm and May was unusually cold. The average of reports of the weather stations at Auburn, Geneva, Hemlock Lake, and Ithaca, all of them in the Finger Lake district, show that April, 1910, was 2.7° C. warmer and May 1.7° C. cooler than the average temperature for those months. In 1911 these conditions were exactly reversed; March and April were somewhat, but not greatly, colder than the average, and May of that year was exceptionally warm. The average of the four stations named shows for April a deficiency of 0.4° C. and for May an excess of 4.1° C. This excess was more noteworthy since the first five days of the month were much colder than the average for that period.

The high temperatures of the hypolimnion and the bottom water in 1910 and their lower condition in 1911 were due to these differences in the weather. The exceptional heat of May, 1911, caused the surface water to warm so rapidly that it prevented the distribution of heat to the deeper water, while the earlier part of the season was so cool that the lakes had warmed but little when the warmer weather began. In 1910 the high temperatures of March and April came while the lakes were still below 4° , or close to that temperature, and the cool weather in May favored the distribution to deeper water of the heat acquired earlier or during that month.

Owasco Lake in 1912 had a bottom temperature slightly higher than in 1910, and that of Skaneateles Lake was much above that of 1910 (see p. 565). No definite general features of the weather in spring can be assigned as the cause; and this is commonly the case, since bottom temperatures ordinarily depend on special events in the weather rather than on its general character.

A word may be said regarding the temperature seiche as an agent for warming the hypolimnion. No observations have been made as yet which show that the temperature seiche has any noteworthy influence in this direction. The warming of the bottom water is effected chiefly in the early part of the season, before the thermocline is established, and while the differences in temperature between surface and bottom are slight. Under these conditions the direct effect of wind is great and that of the temperature seiche is nonexistent or feeble. When the epilimnion has been formed and the temperature seiche can operate vigorously, the thermocline forms the zone of friction, or mixture, of the cooler and warmer water. Its mean descent is very slow, so far as observations have told the facts, after it gets far enough down to escape the ordinary direct influence of the wind, until it begins to sink again in consequence of the autumnal cooling of the lake. Thus it appears that but little work is done by the temperature seiche in carrying the warm water downward, and this work, whether great or small, is mainly expended in extending the lower limits of the epilimnion and has little, if any, effect on the lower water.

WINTER TEMPERATURES.

Seneca and Cayuga Lakes are rarely frozen over except at the ends, and to a small extent along the shores. Local records show that Cayuga Lake was completely frozen in the following winters: 1796, 1816, 1818, 1836, 1856, 1875, 1884, 1904, 1912.^a The

^a The Auk, vol. 29, 1912, p. 438.

length of time that the ice remained is not stated. Seneca Lake has the following record:

1855, closed February 24, opened March 15.
 1875, closed February 9-10, opened March 14.
 1885, closed February 24, opened March 6.
 1912, closed February 11, opened March 10.

Partially closed: 1856, 1865, 1904. Skimmed over with thin ice in spring: May 7, 1829, May 4, 1856, May 5, 1861, May 15, 1872, May 6, 1873, April 26, 1884.^a We are not sure that this spring freezing extended over the entire expanse of the lake.

The other lakes freeze regularly, though the central parts of deeper ones may remain open in mild winters. Freezing usually occurs in January or early February.

Table III gives the important facts for the winter observations made on these lakes. The surface temperature of the lakes which were frozen is that of the water which rose in a hole cut through the ice. The temperatures of the frozen lakes are no doubt subject to less error than are those taken in the open water and more closely represent the mean temperature of the water of the lake. But the lakes were visited during a rather warm and calm period, so there is no reason to believe that any are seriously wrong.

The temperature of Owasco Lake seems very low in 1911, but table IX (p. 560) shows that the lake had lost the same amount of heat per unit of surface as Cayuga Lake. In the same table losses of heat in Seneca Lake seem to be low and those of Skaneateles Lake are high. Yet until we know the range of winter temperatures there is no reason to suspect serious error in either. In 1911 Skaneateles Lake was only partly frozen and the process of cooling was still going on. In 1912 the lakes all froze over early on account of the unusually severe winter and this fact would lead us to expect rather high temperatures for the water of the lakes observed at that time.

TABLE IV.—WINTER TEMPERATURES.

Lakes.	Year.	Condition.	Temperature, surface.	Temperature, bottom.
			° C.	° C.
Cayuga.....	1911	Open.....	2.00	2.75
Owasco.....	1911	Frozen.....	.10	1.20
Owasco.....	1912	.....do.....	.80	2.25
Seneca.....	1911	Open.....	3.25	3.50
Skaneateles.....	1912	Partly frozen..	.70	^a 1.20
Skaneateles.....	1912	Frozen.....	1.00	^b 3.10

^a 50 meters.

^b 75 meters.

MEAN SUMMER TEMPERATURE.

From a series of temperatures taken in the deepest water of the lake, the mean temperature of the water of the lake may be computed. If the mean temperature of each stratum is multiplied by the per cent of that stratum in the total volume of the

^a Data from Prof. E. H. Eaton, Hobart College, Geneva, N. Y.

lake and the several products are added, the result will show the mean temperature of the water. This is shown by the following example:

TABLE V.—METHOD OF COMPUTING MEAN TEMPERATURE OF LAKE: CANANDAIGUA LAKE, AUGUST 20, 1910.

Depth in meters.	Temperature.	Volume.	Product.
		<i>Per cent.</i>	
0-10	21.30	0.221	4.707
10-20	14.50	.184	2.668
20-30	7.40	.165	1.221
30-40	6.25	.147	.907
40-50	5.85	.126	.737
50-60	5.75	.094	.540
60-70	5.65	.049	.277
70-84	5.45	.014	.076
Mean temperature (T_m)=			11.13

These results are, of course, accurate in proportion as the temperatures recorded give a fair picture of the mean temperature of the several strata and in proportion as the hydrographic survey gives a correct account of the volume of the lake. Extreme accuracy can not be claimed in this case for either factor, but the results are approximately correct.

The question has been recently raised, whether a single series of temperatures can give a correct idea of the mean temperature of the water of the entire lake. In a recent review Halbfass^a states that the presence of the temperature seiche makes clear "die Bedeutungslosigkeit einer Beobachtungsserie in vertikaler Richtung in einem vereinzelttem Punkt eines Sees." This statement is entirely too strong, according to my observations, and, indeed, Halbfass in a later paper modifies the statement. No one in recent years would have believed that a single set of observations, or even numerous sets, made at one end of a lake would show the mean temperature of the water, least of all would such a series be trusted if taken during a windy period. This was true long before the temperature seiche was known. Our recent knowledge of the temperature seiche shows that conditions similar to those called out directly by wind may exist at almost any time on account of the oscillations following the influence of winds; hence comes need for increased caution; but it is by no means clear that a single series of temperatures taken under ordinary weather conditions, at or near the center of oscillation of a lake, are "without significance." No one would claim minute accuracy for a result based on such a series; but there is as much reason as ever to believe that from such a series there can be derived a temperature for the water of the lake, which though not minutely exact, is approximately correct—close enough for all purposes of a general discussion. The result is of the right order of magnitude, as the following instances show.

We can not find that many observers have taken series of temperatures with a view of testing the accuracy of results derived from a single series near the middle of

^a Halbfass, W.: Internationale Revue der gesamten Hydrobiologie und Hydrographie, vol. v, 1912, p. 471, Jan., 1913.

the lake as compared with a mean temperature derived from numerous sets of observations, but we have done much work with this end in view. In the New York lakes, series of three or four sets of observations were taken along the axes of three lakes. The results are shown in the following table. In each lake the stations are named from south to north; the mean temperature is computed to the depth of the water at the end stations; and the result from the center station is placed in italics.

TABLE VI.—MEAN TEMPERATURES OF LAKES AS COMPUTED FROM THE SEVERAL SERIES OF OBSERVATIONS, AND FROM THEIR MEAN.

Lakes.	Year.	A.	B.	C.	D.	Mean.
Canandaigua	1910	11.94	<i>12.00</i>	12.50	.....	<i>12.11</i>
Do.	1911	12.17	<i>12.27</i>	12.11	11.96	12.00
Owasco.....	1911	15.34	<i>15.13</i>	14.80	14.82	15.07

EXPLANATION OF TABLE.—The first series is computed to the depth of 50 meters; the second, to 40 meters; the third, to 30 meters, this being the depth of the lake at the end stations. Figures in italics indicate the center station.



FIG. 7.—Mean temperature of Green Lake, Wis. From observations at center of lake in 1911. Computed to depth of 60 meters, the maximum depth at the center. All temperatures lie between 11°, or slightly below, and 12°. The position of the dots along the horizontal axis of the diagram indicates the day and hour of the observation.

The above table shows that the mean temperature deduced from the center series differed by less than 1 per cent from that derived from three or four series. Similar results have been reached in more numerous cases in the Wisconsin lakes. In Lake Mendota in 1911, 1912, and 1913, observations were regularly taken at 10 to 12 different stations so placed as to give the distribution of heat in this lake, which is 9 kilometers long, 6 kilometers wide, and 24 meters deep. In series taken during these years at approximately regular intervals of time on 36 dates from June to September, the maximum departure of the mean temperature derived from the 10 or 12 series from that derived from the single series at the center was less than 3 per cent and this was reached only once; and the mean departure was less than 1 per cent. The maximum differences were in June, when the lake was warming, and the distribution of heat was more irregular than later. In July, August, and September, the maximum departure was about 1.5 per cent and the mean 0.8 per cent.

In five similar series taken in Green Lake, Wisconsin, the maximum departure of the mean temperature derived from the middle series and that derived from all was 5 per cent and the mean was less than 2 per cent.

From July 26 to August 5, 1911, observations to determine the temperature seiche were made on Green Lake. During this work 83 series of temperatures were taken at the middle station. The results are shown in figure 7.

The diagram shows variations between the several observations; and also displays a slow but steady warming of the lake, as would be expected at that date. But for all purposes of a general discussion any one of these results might have been taken as representing the temperature of the lake quite as well as their mean, or as the mean of the several series of observations taken during this period at points along the whole length of the lake.

This general result has been found to be true for observations taken at this time of year in all lakes during many years. It is therefore fair to conclude that the mean temperature of the water of a lake of simple form in late summer may be derived from a single series of observations taken at or near the center of oscillation of the water.

In the New York observations the least satisfactory series is that of Skaneateles Lake in 1911, when time did not permit me to go to the center of the lake. Seneca Lake offered the least favorable situation for taking the temperature in that the deepest water of this lake lies to the south of the center, about one-third of the distance from the south end. At so great a distance from the middle the water is subject to considerable oscillations. During 1910 five series of temperatures were taken from August 2 to August 9. The mean temperature as deduced from the separate series ranged from 7.37° to 8.05° , with a mean of 7.71° —a variation of about 4.5 per cent on each side of the mean. This variation was wholly due to variations in the apparent distribution of the heat and not to actual changes of temperature in the lake, since the temperature of the 0-10 meter layer was practically constant at 19.5° to 19.6° . The 10-20 meter stratum varied from 13.2° to 16.3° —enough to give a difference of 0.28° in the mean temperature. The 20-30 meter stratum varied from 7.3° to 10.2° , which would give a variation of about 0.25° in the mean temperature. Thus the oscillations in the stratum between 10 meters and 30 meters account for about 80 per cent of the range of the temperature, and relatively little is due to changes above or below the depths named. This variation is considerably greater than would be expected in case of the other lakes in which temperatures were taken at the center, or several series were taken along the axis of the lake.

The following table shows the mean temperatures of the lakes as deduced from the observations taken, both for summer and winter.

TABLE VII.—MEAN TEMPERATURE OF THE WATER OF THE NEW YORK LAKES, AS OBSERVED IN SUMMER AND IN WINTER.

Lakes.	Tm ^s , 1910.	Tm ^w , 1911.	Tm ^s , 1911.	Tm ^w , 1912.	Tm ^s , 1912.
Canadice.....	19.32				
Canandaigua.....	11.07		9.99		
Cayuga.....	9.26	2.23	8.94		
Keuka.....	12.17		11.48		
Otisco.....	15.75				
Owasco.....	13.59	0.83	12.86	1.49	13.93
Seneca.....	7.71	3.39	7.35		
Skaneateles.....	10.10	1.10	10.84	2.39	^a 10.21
Green (Wis.).....	11.90	2.13	11.42	1.74	11.96

^a Oct. 18, and therefore below Tm^s. See p. 565.

Table VII shows that the mean temperature of the deeper lakes is lower in summer and higher in winter than that of the shallower, and that the difference between summer and winter temperatures (or the annual range of temperature) is smaller in the case of the deeper lake. This must obviously be true if lakes are similar in other respects but differ in depth.^a The relation in these lakes between area, depth, and mean temperature is much more interesting than this simple statement indicates and will be described on a subsequent page.

ANNUAL HEAT BUDGET.

Forel was the first limnologist—first in this as in so many other matters—to determine the amount of heat absorbed by a lake. He computed the number of calories necessary to raise a column of water of unit base in the deepest part of the lake to the temperature found in summer and he compared on this basis the amount of heat gained by different lakes. This method obviously permits accurate comparison only between lakes of similar area and depth. Halbfass in 1905 improved the method in that he determined the mean temperature of the whole mass of the water of the lake. Knowing the volume of the water he was able to compute the total number of calories contained in the lake and also those gained or lost by the lake as it warmed or cooled. In an elaborate paper he gave the result of this method as applied to many European lakes.^b If this method is employed it is still necessary to select for comparison lakes of similar area and volume.

In our judgment, if the heat budgets of lakes are to be compared at all, it is best to employ units of measurement of such a character that all lakes may be compared with each other, and such that this comparison may, if possible, reveal the relation of area and depth to the amount of the heat budget as well as the relation of geographical position and climate. Since all heat is taken in and given out by the surface of the water it seems best to us to express the amount of heat in the water and its variations in terms of calories per unit of that surface; and on the whole we have decided to employ the same units as those used by the meteorologist for measuring the energy received by the earth from the sun—the gram-calorie and the square centimeter.

If the mean temperature of the water of a lake is known, it is easy to compute the amount of heat which was received by the lake in order to produce this temperature. If the mean temperature of the water is multiplied by the mean depth in centimeters, the result will be the number of gram-calories which the lake must receive on each square centimeter of its surface in order to raise the temperature of the water from 0° C. to the temperature observed. The following table gives this result for the six major New York lakes and also for Green Lake, Wisconsin.

^a For a clear statement of this see Wedderburn, E. M., *Temperatures of Scottish lochs*, in *Bathymetrical survey of the fresh-water lochs of Scotland*, vol. 1, p. 97, 1910.

^b Halbfass, W.: *Ergebnisse neuerer simultaner Temperaturemessungen in einigen tieferen Seen Europas*. Petermanns Mitteilungen, 1910, bd. II, p. 59.

TABLE VIII.—CALORIES PER SQUARE CENTIMETER OF SURFACE REQUIRED TO RAISE TEMPERATURE OF WATER OF LAKE FROM ZERO TO SUMMER TEMPERATURE.

Lakes.	Dm. meters.	Tm ^a 1910.	Calories 1910.	Tm ^a 1911.	Calories 1911.
Canandaigua.....	38.8	11.07	43,000	9.99	39,000
Cayuga.....	54.5	9.26	50,000	8.94	49,000
Keuka.....	30.5	12.17	37,000	11.48	35,000
Owasco.....	29.3	13.59	40,000	12.86	38,000
Seneca.....	88.6	7.71	68,000	7.35	65,000
Skaneateles.....	43.5	10.10	44,000	10.84	47,000
Green (Wisconsin).....	33.1	11.90	39,000	11.42	38,000

It will be seen that the order of the lakes is substantially the same in each year and that the order is that of their depth, as was the case also with their mean temperatures. Keuka, Owasco, and Green Lakes, whose depths are nearly the same, are very close in the amount of heat which they have received. Keuka Lake is the lowest in both years, a result due, like the thinness of the epilimnion, to its sheltered position.

This result represents what may be called the gross heat budget. It can be readily computed but it is of very little value since it does not represent any actual gains of heat. The winter temperature is never as low as zero, and other things being equal, it will be higher in the case of the deeper lake. The most important fact to be known is the annual heat budget of the lake—the amount of heat necessary to raise its water from the winter to the summer temperature—and to determine this we must know both the minimum and the maximum temperature of the water. In case of a lake whose surface freezes, the minimum temperature is that at the time of freezing, although in case of a large lake no great error would result from using any temperature taken during the ice period. In case of a lake that does not freeze, the date and value of the minimum temperature can be ascertained only by a study of the lake during the winter, but a series taken in February will not be far wrong. Such observations were made on four of these lakes in the winter of 1910-11 and two in the winter of 1911-12, with the results shown in the following table. The minimum temperature derived from observations taken in a single winter may be compared with the temperature both of the preceding and following summer; and thus two results can be obtained from three sets of observations. This method has been followed in the table.

TABLE IX.—DIFFERENCE BETWEEN SUMMER AND WINTER TEMPERATURES OF THE SEVERAL LAKES.

[Annual heat budgets stated in gram-calories per square centimeter of the surface of the lake.]

Lakes.	Dm meters.	Tm ^a 1910.	Tm ^w 1911.	Tm ^a 1911.	Tm ^w 1912.	Tm ^a 1912.	Tm ^a 1910 minus Tm ^w 1911.	Calo- ries.	Tm ^a 1911 minus Tm ^w 1911.	Calo- ries.	Tm ^a 1911 minus Tm ^w 1912.	Calo- ries.	Tm ^a 1912 minus Tm ^w 1912.	Calo- ries.
Cayuga.....	54.5	9.26	2.23	8.94	.....	.....	7.03	38,200	6.71	36,500	.....	.....	.....	.....
Owasco.....	29.3	13.59	.83	12.86	1.49	13.93	12.76	38,900	12.03	36,600	11.37	34,700	12.44	37,900
Seneca.....	88.6	7.71	3.39	7.35	.....	.....	4.32	38,300	3.96	35,100	.....	.....	.....	.....
Skaneateles.....	43.5	10.10	1.10	10.84	2.39	^a 10.21	9.00	39,200	9.74	42,400	8.45	36,800	^a 7.82	^a 34,000
Green (Wis.)..	33.1	11.90	2.13	11.42	1.74	11.96	9.77	32,200	9.29	30,600	9.68	31,900	10.22	33,800

^a Taken Oct. 18, and therefore below Tm^a. See p. 565.

The table shows a surprising agreement of the heat budgets of the four lakes compared in 1910. The difference between the highest and the lowest result is only 1,000 calories, or less than the heat which may be furnished to the surface of the lake on a bright summer's day. The agreement in 1911 is nearly as close, with the exception of Skaneateles Lake, and the temperature of that lake was taken at some distance to the north of the center and may possibly be too high, though this result does not appear in the comparisons for 1912. (See also p. 565.) It would be expected that individual variations much greater than 1,000 calories would occur, since both the maximum and minimum temperatures must vary, and if in any individual case a high maximum and a low minimum came in the same season very considerable differences in the heat budget might be present.

The table also shows that the heat budget of successive years is strikingly similar in the case of the same lake. This is especially noticeable in the case of Owasco Lake. It also appears that the heat budget is independent of the depths of the lakes, and also of their other dimensions within the limits of the lakes compared.

The table seems, therefore, to warrant the following conclusions:

1. The annual heat budget of the major New York lakes lies, in general, between 35,000 and 40,000 gram-calories per square centimeter of surface. It may fall below the minimum or rise above the maximum stated, but in general the figures will fall between these numbers.

2. For lakes of the form and size of these the heat budget is apparently independent of surface dimensions between the limits of 16 and 60 kilometers of length, and is independent of depth between the limits of 30 and 90 meters mean depth. It is probable that a lake much shallower than 30 meters would have a smaller heat budget, but a greater depth than 90 meters would produce no effect.

3. Green Lake, Wis., shows results constantly lower than the New York lakes. This is due rather to a high winter minimum than to a low summer maximum. It seems right, therefore, to place this lake in the same general class as the others and to state the following law:

Inland lakes of the first class include those whose area and depth are such as to permit the maximum annual heat budget possible under the weather conditions of the season. Such a budget for lakes in the climatic and topographical conditions of the eastern United States ordinarily equals or exceeds 30,000 gram-calories per square centimeter of the lake's surface, and ordinarily lies between 30,000 and 40,000 gram-calories. Such lakes, under the conditions stated, will be 10 kilometers or more in length and will have a mean depth of 30 meters or more.

This statement applies to lakes of simple outline whose length is five or more times their mean breadth. Lakes of irregular outline can not be compared with those of simple shape, and lakes whose proportions are essentially different from those given are not present in this region in sufficient numbers for study.

4. It is obvious that for more accurate results a careful study of the temperatures of these lakes must be made, so that a mean temperature curve can be determined for each lake and compared with the temperature of the air and with the heat derived from

the sun. Such a study will warrant far more definite conclusions and will probably modify details of the statement given above; but the work would consume several years and would require the combined efforts of many observers.

WIND-DISTRIBUTED HEAT.

The heat budgets of lakes can also be profitably compared in another way, which avoids the necessity of knowing the winter minimum temperature.

The gains of heat in a lake of the temperate type may be divided in two parts, those below 4° and those above. So long as the temperature of the water is below 4° , the surface water becomes denser as it warms; it tends to sink and thus carry the heat into the deeper water. The increase in density is small and the movement, if not aided by the wind, would be slow; but, under the meteorological conditions of early spring, gravity and wind together distribute the warm surface water very rapidly through the water of the lake. Thus there results a rapid and uniform warming of the water. During cold periods the lake loses heat; but since the surface water is only slightly warmer, if at all, than the lower strata, and since any cooling of the surface produces an inverse stratification, the losses which occur during such periods and during the night are ordinarily not great. Thus under usual conditions a lake moves rapidly and steadily up to the temperature of 4° during the spring.

But after this point is reached the situation wholly changes. Increase of temperature in the water means decreased density. Gravity, so far from being an aid to distribution, becomes an opponent; and the wind is left to do substantially the whole work not only without the aid of gravity, but against the resistance which gravity offers.

This resistance is least at 4° and grows with increasing rapidity as the temperature rises above 4° . It follows that the action of the wind is most effective in early spring and becomes less efficient as the season advances and the lake warms. In April, and May also, the mean temperature of the air is above that of the surface of the lake, and losses of heat to the air are at a minimum. Thus in ordinary seasons by far the greater part of the heat which sun and sky furnish to the surface of the lake in April may be stored in its water and is easily carried to considerable depths. The amount thus stored has never been measured for the New York lakes; but for those of Wisconsin as much as 80 per cent or even more may thus be accumulated during April, and during May from 50 to 60 per cent of that which reaches the surface.

As the season advances the mean temperature of the surface rises above that of the air. The thermal resistance of the water to mixture increases and the mean velocity of the wind declines. The gains of heat fall off correspondingly. Not more than 15 or 20 per cent of the heat which falls on the surface of the lake is stored up in June, perhaps not more than 5 per cent in July, while in August the gains and losses of heat nearly balance.^a

But during much of this period of decrease in storage, the quantity of heat delivered to the surface of the lake is increasing, that for July being ordinarily near the maximum

^a The general principles of this statement hold for all lakes. Numbers and dates will vary somewhat with the area and depth of the individual lake.

for the year and that for August not greatly below this. It follows that there is a great surplus of heat, potentially available for warming the lake, which is lost to the lake because the means for distributing it are inefficient.

If 40,000 gram-calories represents the maximum heat budget of such a lake, this is little more than half the amount of heat delivered by sun and sky between April 1 and August 31. If 25,000 to 30,000 gram-calories represents a fair average for the wind-distributed heat, this again is less than half the heat delivered during that part of the warming period after the water of the lake has passed 4° .

The following conclusions are therefore warranted:

1. All lakes, whatever their area or depth, are on an approximate equality so far as their capacity for absorbing heat is concerned until their water has reached the temperature of maximum density, or 4° , and this temperature is reached by all lakes early in the open season.

2. The amount of heat absorbed after the temperature of 4° is passed, depends primarily on the efficiency with which the heat is carried from the surface to the deeper water, and this work is mainly effected by the wind.

3. If we compare the gains of heat above 4° made by different lakes, we compare their wind-distributed heat, and so are able to compare the efficiency of their means of distribution. If the climatic and topographic conditions are similar, the efficiency of the means of distribution will increase with the dimensions and the depth of the lake up to a certain point.

4. Since lakes reach the temperature of 4° early in the season, a comparison of their gains above 4° serves much the same purpose as a comparison of their annual heat budgets.

To these statements there are several qualifications, none of which have been worked out quantitatively and only one of which need be stated.

The amount of heat needed to raise the temperature of a lake from its winter condition to 4° may vary very greatly, especially in case of lakes that freeze. It is probable that more complete observations will show a greater proportionate range of variation in the amount to which lakes cool below the temperature of 4° than in the rise above 4° . The following table shows the facts for the lakes in question.

TABLE X.—CALORIES PER SQUARE CENTIMETER OF SURFACE REQUIRED TO RAISE WATER OF LAKES FROM WINTER TEMPERATURE TO 4° AND FROM 4° TO SUMMER TEMPERATURE.

Lakes.	Calories, T_m^w to 4° , 1911.	Calories, 4° to T_m^s , 1910.	Calories, T_m^w to 4° , 1912.	Calories, 4° to T_m^s , 1911.
Cayuga.....	9,600	28,600	.....	26,900
Owasco.....	9,400	28,100	7,400	26,000
Seneca.....	5,400	32,900	.....	29,700
Skaneateles.....	12,600	26,600	7,000	29,300
Green.....	6,200	26,000	7,500	25,900

It appears, therefore, that it may require as much as a month's supply of heat, or even more, to raise the temperature of the lake from its winter condition to 4° . In such cases as that of Skaneateles Lake in 1910, it is possible that the lake may reach

4° so late that the whole season of later warming may be thrown over into the period when days are long and winds are light. Thus there might be a correspondingly small amount of wind-distributed heat. As a matter of fact, this result did not happen in the case cited, since Skaneateles Lake gained its full quota of heat in 1911 and this will usually be the case.

The last heat gained by a lake is in the epilimnion and therefore is near the surface—in the New York lakes not below 15 meters. The wind velocity from mid-July on through August is not essentially less than it is during the preceding six weeks. The surface is still receiving a great amount of heat, and the increasing length of the night adds to the chances of distribution. Thus in general a lake gains by the middle of August all of the heat that the wind can get into its depths; and whether a lake starts to accumulate its wind-distributed heat two weeks or so earlier or later makes little if any difference in the general result. In any case the heat is supplied to the deeper water of the lake early in the season before the velocity of the wind has greatly fallen.

TABLE XI.—CALORIES PER SQUARE CENTIMETER OF SURFACE NEEDED TO RAISE WATER OF LAKES FROM 4° TO SUMMER TEMPERATURE, OR THE AMOUNT OF WIND-DISTRIBUTED HEAT.

Lakes.	Dm. meters.	Tm ^a -4, 1910.	Calories.	Tm ^a -4, 1911.	Calories.	Tm ^a -4, 1912.	Calories.
Canandaigua.....	38.8	7.07	27,400	5.99	23,200	.....	.....
Cayuga.....	54.5	5.26	28,600	4.94	26,900	.....	.....
Keuka.....	30.5	8.17	24,900	7.48	22,800	.....	.....
Owasco.....	29.3	9.59	28,100	8.86	26,000	9.93	29,000
Seneca.....	88.6	3.71	32,900	3.35	29,700	.....	.....
Skaneateles.....	43.5	6.10	26,700	6.84	29,700	.....	(a)
Green (Wis.).....	33.1	7.90	25,900	7.42	23,500	7.96	26,000

^a See p. 565.

Table XI shows that Keuka Lake has the smallest amount of wind-distributed heat in both years and Seneca Lake the largest. So far as the former lake is concerned, it seems probable that this will be the regular condition, the narrowness of the lake and its steeper banks reducing the influence of the wind. It is not so certain that the result in Seneca Lake will be confirmed by further study, although this conclusion seems probable. No two lakes can be more nearly equal in area or similar in topographical condition than are Seneca and Cayuga Lakes. But three factors contribute to give Seneca an advantage in gaining heat during the early part of the season—steeper slopes, greater depth, and greater volume. The result of these was that Seneca Lake absorbed more heat into its deeper water than did Cayuga in 1910. The water of Seneca Lake below 30 meters received 1,600 calories per square centimeter of the surface of the lake more than the corresponding water of Cayuga, and in 1911 the excess was about 300 calories.

The steeper sides of Seneca Lake give it an advantage in distributing heat to the deeper water, since the large shoal areas at the north end of Cayuga Lake tend to keep the return currents near the surface; but the chief advantage of Seneca Lake is in the greater reduced thickness (p. 566) of its several strata. If the results for Cayuga and

Seneca Lakes are compared in table XII, it will be seen that the water of Cayuga Lake has a higher temperature than the corresponding stratum of Seneca Lake, but the strata of Seneca have the greater reduced thickness and so contain more heat.

But for the present the most important conclusion from the table lies in the general fact that for lakes 10 kilometers or more in length and 30 meters or more in mean depth, the annual gains of wind-distributed heat are on the whole independent of area or depth and range from something below 25,000 calories to something above 30,000 calories. It is not asserted that in these lakes different areas and depths have no effect. The contrary is true, as is shown above, but in general these effects lie within the range of the variation due to local conditions in wind and weather. No doubt under exactly similar conditions the largest and deepest lake will gain most heat, but the effects of area and depth are such that they may be overcome by variations of weather. In 1910, for instance, Owasco Lake, the smallest and shallowest of the New York group, stands third in the amount of heat, and in 1911 Skaneateles Lake is equal to Seneca Lake and is much above the far larger and deeper Cayuga Lake.

From these facts we may give a second definition for inland lakes of the first class: In inland lakes of the first class the wind-distributed heat, $Dm(Tm^s - 4)$, is about 25,000 gram-calories per square centimeter of surface and usually exceeds that sum. Such lakes will be, under the climatic conditions of the eastern United States, 10 kilometers or more long and will have a mean depth of 30 meters or more. If such a lake falls below 25,000 calories, the deficiency will be due to exceptional conditions of topography or weather. If its gains rise above 30,000 calories, this result will also be exceptional. Further study is needed to make these statements more accurate in detail. Such study will show the presence and limits of the influence of area and depth within this class of lakes.

In 1912 temperatures were read in Skaneateles Lake on October 18, too late for the maximum temperature of the upper water. The water at the bottom was 6.3° , much higher than in 1910 or 1911. The temperatures below the depth of 40 meters would be practically unaltered on October 18. If these are taken as they were found, and if we assume that the temperature of the water above 40 meters was the same in 1912 as in 1910, then Tm^s for 1912 would be 10.72° . If we, in like manner, assume for 1912 the same temperature for the upper water as in 1911, then Tm^s 1912 would be 11.33° . On the basis of the latter figures the maximum annual heat budget between Tm^w 1911 (11.10°) and Tm^s 1912 (11.33°) would be 44,500 gram-calories. This shows that under favorable conditions the annual heat budget of these lakes may go as high as 45,000 gram-calories per square centimeter. The wind-distributed heat in 1912 for Skaneateles Lake on these assumptions would be 29,200 gram-calories and 31,800 gram-calories, respectively.

DISTRIBUTION OF HEAT.

Distribution to thermal regions (fig. 8).—The formula for the amount of wind-distributed heat is $Dm(Tm^s - 4)$. The product is the number of gram-calories per square centimeter of surface which the lake must receive that its temperature may

rise from 4° to its summer temperature. In what proportion is this heat so received distributed to the three main thermal regions?

In order to answer this question the mean temperature of each region must be known, and to determine this the reduced thickness of each region must be ascertained.

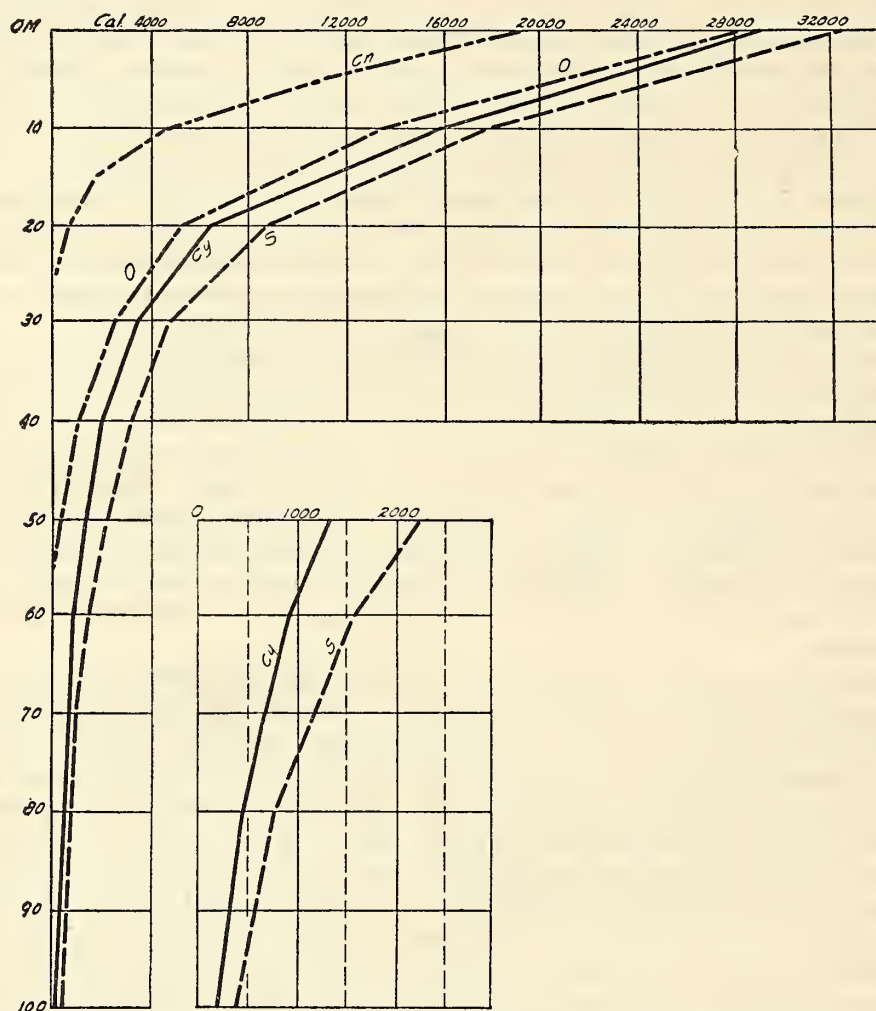


FIG. 8.—Distribution of wind-distributed heat in 1910, in Canadice (Cn), Owasco (O), Cayuga (Cy), and Seneca (S) Lakes. Depth in meters; heat in gram-calories per square centimeter of surface of the lakes. Diagram extends to 100 meters. The curves of Seneca and Cayuga Lakes, from 50 meters to 100 meters, are repeated on a more open scale. (See p. 572.)

In table XII the column marked "Extent" shows the thickness of each thermal region as measured in meters below the surface of the lake; the column marked "R. T." (reduced thickness), shows its thickness as referred to the area of the surface of the lake.

It is ascertained, like the mean depth of the lake, by dividing the volume of the water of the region by the area of the surface. The reduced thickness of the region thus differs from its mean thickness in that the reduced thickness of the region is in all cases referred to the area of the surface of the lake, while the mean thickness of a given stratum would be its thickness referred (ordinarily) to its own upper boundary plane. Table XII shows the distribution of the calories received by a unit of the surface of the six major lakes to their thermal regions.

TABLE XII.—SHOWING EXTENT AND REDUCED THICKNESS OF THE THREE THERMAL REGIONS IN THE SIX MAJOR LAKES, THEIR TEMPERATURE, AND THE NUMBER OF CALORIES PER SQUARE CENTIMETER OF SURFACE OF THE LAKE DISTRIBUTED TO EACH REGION.

[The sums of the calories in each lake may differ slightly from those given in the general table, owing to the different method of computation.]

Region.	Ex- tent.	R. T.	Tm-4.	Calo- ries.	Per cent.	Region.	Ex- tent.	R. T.	Tm-4.	Calo- ries.	Per cent.
CANANDAIGUA LAKE, 1910.	<i>Meters.</i>	<i>Meters.</i>				OWASCO LAKE, 1910.	<i>Meters.</i>	<i>Meters.</i>			
Epilimnion.....	0-12	10.0	16.8	16,800	61.9	Epilimnion.....	0-12	10.6	16.3	17,300	61.6
Thermocline.....	12-20	5.6	9.3	5,200	19.1	Thermocline.....	12-20	5.6	9.9	5,600	19.7
Hypolimnion.....	20-84	23.1	2.73	5,200	19.0	Hypolimnion.....	20-54	13.1	4.0	5,200	18.7
	.....	38.7	7.07	27,200	.....		.....	29.3	9.59	28,100	.....
CANANDAIGUA LAKE, 1911.						OWASCO LAKE, 1911.					
Epilimnion.....	0-12	10.0	15.5	15,500	66.4	Epilimnion.....	0-12	10.6	15.9	16,800	64.5
Thermocline.....	12-20	5.6	9.2	5,200	22.0	Thermocline.....	12-20	5.6	10.6	6,000	22.8
Hypolimnion.....	20-84	23.1	1.04	2,400	11.6	Hypolimnion.....	20-54	13.1	2.41	3,200	12.7
	.....	38.7	5.99	23,200	.....		.....	29.3	8.86	26,000	.....
CAYUGA LAKE, 1910.						SENECA LAKE, 1910.					
Epilimnion.....	0-15	11.8	15.5	18,300	64.2	Epilimnion.....	0-12	11.5	15.4	17,700	53.8
Thermocline.....	15-22	4.62	10.3	4,800	16.9	Thermocline.....	12-20	6.2	10.2	6,400	19.5
Hypolimnion.....	22-133	38.3	1.41	5,400	18.9	Hypolimnion.....	20-188	70.9	1.21	8,800	21.7
	.....	54.7	5.26	28,500	.....		.....	88.6	3.71	32,900	.....
CAYUGA LAKE, 1911.						SENECA LAKE, 1911.					
Epilimnion.....	0-16	12.5	15.2	19,000	71.1	Epilimnion.....	0-15	13.8	15.4	21,200	71.5
Thermocline.....	16-21	3.3	9.2	3,300	12.4	Thermocline.....	15-22	6.0	8.6	5,200	17.5
Hypolimnion.....	21-133	38.7	1.14	4,400	16.5	Hypolimnion.....	22-188	68.8	0.47	3,300	11.0
	.....	54.7	4.94	26,700	.....		.....	88.6	3.35	29,700	.....
KEUKA LAKE, 1910.						SKANEATELES LAKE, 1910.					
Epilimnion.....	0-9	8.4	16.8	14,100	56.6	Epilimnion.....	0-9	8.0	15.7	12,500	46.9
Thermocline.....	9-15	4.9	9.2	4,500	18.1	Thermocline.....	9-18	6.5	10.1	6,600	24.7
Hypolimnion.....	15-56	17.2	3.45	6,300	25.3	Hypolimnion.....	18-90	29.0	2.97	7,600	28.4
	.....	30.5	8.17	24,900	.....		.....	43.5	6.10	26,700	.....
KEUKA LAKE, 1911.						SKANEATELES LAKE, 1911.					
Epilimnion.....	0-11	10.0	16.2	16,200	71.0	Epilimnion.....	0-16	13.0	15.5	20,200	67.8
Thermocline.....	11-18	5.4	7.8	4,100	18.0	Thermocline.....	16-22	4.2	10.4	4,300	14.4
Hypolimnion.....	18-56	15.1	1.68	2,500	11.0	Hypolimnion.....	22-90	26.3	1.82	4,700	17.8
	.....	30.5	7.48	22,800	.....		.....	43.5	6.74	29,200	.....

Inspection of table XII shows that the mean temperature of the epilimnion and the thermocline are not very variable in the six major lakes. In the first region Tm^{s-4} equals 15.66° , as the mean of 12 observations, ranging from 15.2° to 16.8° . For the thermocline the mean is 9.56° , ranging from 7.8° to 10.6° . The differences in the amount of heat stored by a lake in these regions are due much more to the thickness of the stratum than to its temperature. For instance, in Seneca Lake in 1910 the temperature of the thermocline was 19.4° , and in Skaneateles Lake in 1910 it was 19.7° . But its thickness in Seneca Lake was 15 meters, and only 9 meters in Skaneateles; and the wind-distributed heat in the epilimnion of the former lake was therefore over 75 per cent greater than that of the latter.

It appears from the table that a very large part of the wind-distributed heat is in the epilimnion. The upper 10 or 15 meters of a lake, even 60 kilometers long and nearly 200 meters deep, contain 50 to 70 per cent of the heat, or even more. If to this stratum is added that which lies immediately below it and has derived its heat from it, it appears that the upper 20 meters contain 70 to 80 per cent, or even 90 per cent, of the wind-distributed heat. (See table XIII.) This limitation of the heat to the upper strata is responsible not only for the sharply-defined thermocline, but also for the general uniformity in the amount of wind-distributed heat in the heat budget of the several lakes. A large percentage of the heat is always near the surface in summer. During the period of light winds and summer weather, when heat is furnished far in excess of the capacity of the distributing agents, so much is lost in any case that there is enough for any lake to get the maximum possible supply, and any deficiency is likely to be due to the distributing agents, and not to lack of supply. Still more, any loss caused by a short cool period during the summer may be quickly repaired, since no violent wind is needed to distribute the heat to water near the surface. Indeed, such a cool period may well be the indirect cause of the gain of heat. It allows the heat already in the lake to be distributed to a greater depth, while the surface will rapidly renew its supply during the succeeding warm days.

The heat distributed to the hypolimnion is extremely variable both in quantity and in the per cent it constitutes of the total heat. If the sums of the calories found in the epilimnion and thermocline are compared for the 12 observations, it will be found that the mean is 22,200. The mean departure of each observation from the mean is about 8 per cent; the maximum departures are +19 per cent and -16 per cent; and the range is about 35 per cent of the mean. In the case of the hypolimnion the mean amount of heat is 4,900 calories. The mean departure of each observation is 28 per cent of this sum, the maximum is +80 per cent and -50 per cent, with a range of 130 per cent of the mean. Not only so, but the difference in the same lake in successive years is even more striking. The hypolimnion of Seneca Lake received 8,800 calories per square centimeter of surface in 1910, and only 3,250 calories in 1911. Keuka Lake had 6,300 calories in 1910 and 2,700 calories in 1911. The mean of the six lakes for 1911 was hardly more than half as great as that for 1910 (6,400 and 3,400 calories), and the largest amount in 1911 (4,800 calories in Skaneateles Lake) was below the

smallest of the former year (5,000 calories in Cayuga Lake). This distribution illustrates several principles.

1. The amount of heat received by the hypolimnion depended on the vicissitudes of weather during the early part of the warming period. (See p. 553.)

2. The lakes of the district were all similarly affected in each year.

3. In spite of this general similarity there are great individual differences, and neither the size nor the depth of the lake seem to be decisive in influencing the amount of heat given to the hypolimnion. In 1910 Skaneateles Lake, with a hypolimnion 72 meters in maximum thickness and 29 meters in mean thickness, received 7,600 calories. Seneca Lake, with a hypolimnion 168 meters in maximum thickness and 71 meters in mean thickness, received only 8,800 calories. This was true in spite of the fact that Seneca Lake is far larger and its hypolimnion began only 2 meters farther from the surface. In 1911 Seneca Lake received less heat in its hypolimnion than Skaneateles Lake (3,250 calories and 4,800 calories, respectively); less than Cayuga Lake (4,400 calories); and practically the same as Owasco Lake (3,150 calories), the smallest and shallowest of the lakes.

Distribution to the several 10-meter strata.—It will be of interest to consider the distribution of heat by the wind to different depths below the surface, as well as its distribution to the different thermal regions. This distribution may be expressed in two ways:

1. The heat absorbed by each square centimeter of the surface may be followed through the lake and the amount determined which is absorbed by or passed through each successive stratum, and the result may be expressed in calories per square centimeter of the surface of the lake.

2. The boundary planes of the successive strata of the lake become smaller in proportion to their distance from the surface. It is possible, therefore, to state not merely the number of calories per square centimeter of the lake's surface which pass through any given plane, but also the number of calories which pass through each centimeter of the plane itself.

An example will make this clear. The water of Cayuga Lake absorbed 28,600 gram-calories through each square centimeter of the surface in 1910; 12,800 calories were left in the 0-10 meter stratum. Thus there remained at 10 meters 15,800 calories of those received by each square centimeter of the surface, and this amount was distributed to the water below the depth of 10 meters. But the area of the lake at 10 meters is 72.5 per cent of the surface area, and the number of calories which passed through each square centimeter of this plane is correspondingly greater. Through each square centimeter of the 10-meter plane there passed 21,800 calories, or $\frac{15,800}{0.725}$.

TABLE XIII.—DISTRIBUTION OF HEAT TO THE SEVERAL 10-METER OR 5-METER STRATA—Continued.

SENECA LAKE.

Depth, meters.	Calories per square centimeter of sur- face remaining at depth named.				Calories per square centimeter of area at depth named.		Depth, meters.	R. T., meters.	Calories per square centimeter of surface left between depths named.			
	1910	Per cent.	1911	Per cent.	1910	1911			1910	Per cent.	1911	Per cent.
0	32,900	100.0	29,600	100.0	32,900	29,600	0-10	9.35	14,600	44.4	14,600	49.5
10	18,300	55.6	15,000	50.5	21,000	17,200	10-20	8.40	9,600	29.2	10,200	34.3
20	8,700	26.4	4,800	16.2	10,800	6,000	20-30	7.86	3,700	11.2	2,600	8.8
30	5,000	15.2	2,200	7.4	6,600	2,900	30-40	7.41	1,800	5.5	800	2.7
40	3,200	9.7	1,400	4.7	4,500	2,000	40-50	6.92	1,000	3.0	400	1.3
50	2,200	6.7	1,000	3.4	3,300	1,500	50-60	6.49	600	1.8	280	1.0
60	1,600	4.9	720	2.4	2,600	1,200	60-70	5.89	450	1.4	160	.6
70	1,150	3.5	540	1.8	2,000	950	70-80	5.52	320	1.0	160	.6
80	830	2.5	380	1.3	800	700	80-100	9.82	460	1.4	200	.7
100	370	1.1	180	.7	800	400	100-150	20.2	305	.9	178	.7
150	65	.2	2	.....	290	10	150-188	3.3	65	.2	2	.....
188	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

SKANEATELES LAKE.

0	26,700	100.0	29,700	100.0	26,700	29,700	0-10	8.75	13,700	51.3	13,600	45.8
10	13,000	48.7	16,100	54.2	17,000	21,300	10-20	7.14	6,400	24.0	9,900	33.3
20	6,600	24.7	6,200	20.9	9,800	9,200	20-30	6.39	2,300	18.6	3,100	10.4
30	4,300	16.1	3,100	10.5	7,100	5,100	30-40	5.75	1,500	5.6	1,200	4.1
40	2,800	10.5	1,900	6.4	5,200	3,400	40-50	5.06	1,100	4.1	900	3.0
50	1,700	6.4	1,000	3.4	3,700	2,200	50-60	4.28	730	2.8	510	1.8
60	970	3.6	490	1.6	2,500	1,300	60-70	3.37	560	2.1	340	1.1
70	410	1.5	150	.5	1,400	520	70-80	2.13	330	1.2	110	.4
80	80	.3	40	.1	550	220	80-90	.56	80	.3	40	.1
90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

CANADICE LAKE, 1910.

0	19,400	100.0	.....	.....	19,400	.....	0-5	4.54	8,200	42.3	.....	.....
5	11,200	57.7	.....	.....	13,400	.....	5-10	4.00	6,500	33.5	.....	.....
10	4,700	24.2	.....	.....	6,200	.....	10-15	3.48	2,700	13.9	.....	.....
15	2,000	10.3	.....	.....	3,200	.....	15-20	2.79	1,300	6.7	.....	.....
20	700	3.6	.....	.....	1,300	.....	20-25	1.59	700	3.6	.....	.....
25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

OTISCO LAKE, 1910.

0	17,000	100.0	.....	.....	17,000	.....	0-5	4.22	7,900	46.5	.....	.....
5	9,100	53.5	.....	.....	13,000	.....	5-10	3.25	5,400	31.8	.....	.....
10	3,700	21.8	.....	.....	6,200	.....	10-15	2.79	2,900	17.1	.....	.....
15	800	4.7	.....	.....	1,550	.....	15-20	.94	800	4.7	.....	.....
20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

The above table shows the amount and per cent of the total heat absorbed by the surface which is left in each 10-meter stratum of the lakes studied. The rapidity with which the heat declines is evident, and shows how hard the wind finds the task of overcoming the thermal resistance. A single illustration shows this in a striking manner. We may allow 1,000 calories per square centimeter as a full (not a mean) supply to the surface for a single summer day. We find in the various major lakes that this amount was distributed in 1910 to the water below a depth of 35 to 60 meters, and below 30 to 50 meters in 1911. Thus the work of the entire season was necessary to carry to

a depth greater than the number stated an amount of heat equal to one maximum day's supply in summer.

Nor is this all. The upper 10 meters contain from 45 to 65 per cent or more of the heat absorbed. This region is that in which nocturnal cooling, the action of waves, and the direct penetration of the sun aid in distributing the heat. At depths where these agencies cease to act the influence of the wind declines very rapidly.

It is worth while to call attention to the fact that the distribution of heat is strikingly similar in each year and that the two years show marked differences.

Figure 8 (p. 566) shows in graphic form the results for 1910 in the case of Owasco Lake and Seneca and Cayuga Lakes, respectively the largest and deepest and the smallest and shallowest of the lakes. The greater quantity of heat in Seneca Lake was due almost wholly to the greater amount distributed to the hypolimnion, that in the epilimnion and thermocline being about equal in both lakes. It thus appears that in general the distribution of heat is independent of the area or depth of the lakes, in the case of lakes of the first class. The mean of observations made in Green Lake, Wisconsin, during 10 or 12 years falls midway between the results for Cayuga Lake in 1910 and 1911, and shows that this lake also belongs to lakes of the first class. The curve of heat distribution for Canadice Lake is added to show the facts for a smaller lake.

HEAT SUPPLY OF THE SMALLER LAKES.

We must now consider the heat supply of the two smaller lakes, of which we have hydrographic surveys, Canadice and Otisco. We are unable to discuss their annual heat budget, as no winter observations have been made on them, but the amount of wind-distributed heat can easily be ascertained. It will be remembered that Otisco Lake has an available length of about 7.33 kilometers and a mean breadth of 0.93 kilometers; its maximum depth is 20.1 meters, and its mean depth 11.2 meters. The corresponding figures for Canadice Lake are: Length, 5.12 kilometers; mean breadth, 0.51 kilometers; maximum depth, 25.4 meters; mean depth, 16.4 meters. The ratio $\frac{D_m}{D_{mx}}$ is about 0.53 in Otisco, which is not far from the mean of that in case of the six deeper lakes. In Canadice Lake $\frac{D_m}{D_{mx}} = 0.64$, a number nearly one-third higher than the mean of the other lakes and about 16 per cent greater than the highest one. This fact is of great influence on the heat supply of Canadice Lake.

Both lakes are small and shallow as compared with those which have been discussed. Their mean temperature is correspondingly high (Otisco, 19.2°; Canadice, 15.8°). Both temperatures, and especially that of Otisco, are much above that of the deeper lakes. The mean depth, however, is so small that the total amount of wind-distributed heat, $D_m (T_m^s - 4)$, is much smaller. In Canadice this sum is 19,400 gram-calories per square centimeter of surface, and in Otisco Lake the amount is still smaller, 17,000 gram-calories. It appears therefore that Canadice Lake accumulates about 80 per cent as much heat per unit of surface as the larger lakes and Otisco Lake about 65 per cent as much.

No discussion of these facts would be possible if it was based on the single series of observations made on each of these lakes, but these can be interpreted in the light of the almost innumerable observations on Wisconsin lakes, and considered in this light they are extremely interesting.

The influence of the small size of the lake is apparent in the shallow epilimnion—7 meters, or a little more than half its thickness in the larger lakes. The same general relation is shown by other similar facts. The temperature of the lower water is raised above 4° by mixture; and the depth at which this water reaches temperatures of 10° or 15° in August will give, like the position of the thermocline, the approximate value of the mixing power of the wind. In 1910 the temperature of 15° lay at about 10 meters in Canadice Lake, 11 meters in Otisco, 18.5 meters in Cayuga, 15 meters in Seneca and Owasco. The temperature of 10° lay at 14 meters in Canadice, from 20 to 25 meters in the other lakes. In Otisco the bottom water at 20 meters had a temperature of 12° . The bottom of the epilimnion marks the lower limit of the direct distribution of heat in summer, and its position in the various lakes is the best measure of the relative influence of the wind on them. The depth of the successive isotherms also marks the approximate levels of wind influences. As would be expected, these levels are higher in the smaller lakes, and their smaller dimensions form the first reason for their smaller gain of heat.

The second reason lies in the smaller mean depth of the lake and the smaller reduced thickness of each stratum. In a shallow lake the heating surface is greater in proportion to the depth than in a deeper lake, and it might therefore be expected that the former lake would be proportionately higher in temperature, and that the number of calories gained per square centimeter of surface would be the same in the two lakes so that the product Dm (Tm^s-4) would be nearly constant for all lakes as it is for those of the first class. It might be expected, for instance, that if Canadice Lake ($Dm=16.4$ meters) gained 19,400 calories of wind-distributed heat, then in Otisco Lake, with a mean depth of 11.2 meters, Tm^s-4 would be high enough to make the product about the same, so that the two lakes would gain the same amount of heat from an equal heating surface. This might be expected the more readily as Otisco is the larger lake and has a relatively larger surface; but so far from reaching this result, Otisco Lake has gained only about 17,000 calories, or nearly 9 per cent less than the deeper lake.

There are two reasons for this disadvantage of a shallow lake. First, the temperature of the epilimnion is determined not only by the relation of insolation and wind action, but even more by losses to the air. A shallow epilimnion ordinarily reaches a higher temperature than a thicker one, but the difference in the temperature is not so great as in the reduced thickness, so that the total amount of heat in the epilimnion is smaller. The losses to the air prevent the temperature from rising above a certain point. If, for instance, the epilimnion of Canadice Lake were to have as much heat as even that of Keuka, whose epilimnion is the thinnest of the six major lakes, $Tm-4$ would have to be 22.3° , and Tm 26.3° . This is an obviously impossible temperature as the mean of any considerable stratum, since in our latitudes it is reached only by a very thin surface layer in the hottest part of bright calm days. It rarely persists overnight.

This difference between the deep and shallow lakes, however, is relatively less apparent in the epilimnion than in the thermocline and hypolimnion. In these regions the second disadvantageous factor of the shallower lake comes in with more influence. The gains of heat of the water in and below the thermocline depend wholly on mechanical mixture. There are no gains from the sun and no losses to the air and practically no losses by conduction. Hence the thermal resistance to mixture^a is the factor which resists the transfer of heat downward, and the influence of the wind, direct or indirect, is the force which carries the heat down. But the thermal resistance increases much more rapidly than the temperature rises and soon puts an end to the force of the wind in carrying the heat downward. If we compare the thermocline of Otisco and Canadice Lakes, we find that the region is included between the same levels in both lakes and that the temperature is not greatly different (Canadice, 12.9°; Otisco, 13.2°). The advantage in temperature is on the side of the shallower lake. But the reduced thickness of the region in Otisco Lake is only 3.05 meters as against 3.76 meters in Canadice. The total amount of heat in the region is therefore about 17 per cent less.

If the thermocline of Otisco Lake were to derive as much heat from each square centimeter of surface as did that of Canadice, T_m-4 for that region must be 15.7°, or 2.5° above that actually reached. A great amount of energy is needed to produce this increase from 13.2° to 15.7° by mixture. The increase of temperature is about 19 per cent but the work to be done in effecting this increase is much greater than that.

The work to be done in warming a stratum of water which lies below the direct influence of the sun is done against gravity which resists the descent of the warmer and lighter water. The net work done in warming a stratum of water to a given degree may be measured by the energy which would be needed to transport the mass of water, thus warmed, to the place where it is found, against the resistance of denser water at a temperature of 4°. We may think of such a stratum as pushed down to its place through water at 4°, somewhat as a sheet of cork might be forced down through the water. The weight to be moved is the difference in weight between the warmed water and water at the temperature of maximum density. The distance through which it is carried is the mean distance of the stratum in question from the surface.

In this case the difference in the amount of work necessary to warm the thermocline to 13.2° and 15.7° is proportional to the difference in loss of weight of water at these temperatures. A liter of water at 13.2° weighs 621 milligrams less than at 4°, and this is the weight of each liter to be used in computing the work done in warming the thermocline. At 15.7° the weight of a liter is 982 milligrams less than at 4°. Thus over one-half must be added to the work which was done in warming the water to 13.2°, if 2.5°, or about 19 per cent, are added to the heat.

A similar statement may be made for the hypolimnion. If this region in Otisco Lake is to receive as many calories per square centimeter of the surface of the lake as does that of Canadice, its temperature will rise to 12°. But to effect this rise would require, if measured on the same basis as in the former example, more than three times

^a Birge, Edward A.: An unregarded factor in lake temperatures. Transactions Wisconsin Academy of Sciences, vol. xvi, pt. 2, p. 989. 1910.

as much work as that which was actually available for warming it. This is obviously a demand impossible to satisfy.

Thus the shallow lake has a double disadvantage. Its smaller reduced thickness for any given stratum diminishes the volume of water into which heat may be distributed from the surface. This deficiency of volume can not be compensated by an equivalent rise of temperature, since the amount of energy present to mix the water is soon exhausted by the rapid rise of thermal resistance to mixture as the temperature increases.

The shallow lake has an advantage in one respect, probably a small advantage but one whose amount has not been determined. What may be called its mixing areas are more efficient because of the gradual slope of the bottom. Consider the condition of the lake with direct thermal stratification, whose form is that of an oblong tank with vertical sides. A wind blowing the surface water to one end would depress the isotherms there. The cold water would swing back and oscillate, but there would be very little friction between the strata and little mixture and correspondingly little warming of the lower water. In an actual lake with sloping bottom, the narrower ends concentrate and give force to the movements of the water caused by the wind and increase the amount of mixture due both to the direct and indirect effects of the wind. As the warm water is forced downward at the ends, it squeezes out the cooler water in a relatively thin layer between the descending surface of the epilimnion and the gradually sloping bottom of the lake. As the cool water swings back, its edge pushes in like a wedge between the bottom and the epilimnion. Both movements are attended with relatively great friction and corresponding mixture of the warmer and cooler water. Thus the ends of the lake constitute its chief mixing areas, and they are the region where the gradual warming of the thermocline and hypolimnion goes on most rapidly. Relatively little warming is effected in the open water of the lake or on its steep sides where movement, which is chiefly lateral, is attended with little resistance and consequent mixture. In this respect, therefore, the shallow lake has an advantage over the deeper one whose slopes are steeper. The shallowness of the water is also an advantage in the spring before the thermocline is formed, in that the water is nearer the surface and so more readily accessible to the influence of the wind. Thus its temperature rises above that of the deeper lake, but it never reaches a point, under conditions otherwise equal, high enough to give it as great a total amount of heat per unit of surface as the deeper lake accumulates.

TABLE XIV.—EXTENT, REDUCED THICKNESS, AND HEAT SUPPLY OF THE THERMAL REGIONS OF CANADICE AND OTISCO LAKES.

Region.	Extent, meters.	R. T. meters.	Tm°-4.	Calories.	Per cent.
CANADICE LAKE, 1910.					
Epilimnion.....	0-7	6.33	18.2	11,500	58.8
Thermocline.....	7-12	3.76	12.9	4,800	24.8
Hypolimnion.....	12-25	6.28	4.93	3,100	16.2
OTISCO LAKE, 1910.					
Epilimnion.....	0-7	5.57	18.8	10,500	62.7
Thermocline.....	7-12	3.05	13.2	4,000	24.1
Hypolimnion.....	12-20	2.58	8.4	2,200	12.3

DISSOLVED GASES.

METHODS OF OBSERVATION.

During the month of August, 1910, observations were made on 10 of the Finger Lake for the purpose of ascertaining the amount of dissolved oxygen and carbon dioxide in their waters. The samples of water for these determinations were obtained either by means of a pump and hose or with a closing water bottle. With one exception the former method was used at all depths in the shallower lakes—that is, those not exceeding 30 meters (100 feet) in depth—and in the upper water of the deep lakes. The water bottle was used on Otisco Lake and in the lower strata of the deep lakes.

The Winkler method was used for the determination of the quantity of dissolved oxygen and the Seyler method for the carbon dioxide. These methods have been fully described in a previous publication,^a and further consideration of them is not necessary here. A new table of oxygen saturations (table XXI, p. 609) is included as a substitute for the previous one. It is based upon the more recent determinations of Fox,^b who gives the results for degrees centigrade from -2° to $+30^{\circ}$. The intervening tenths of degrees have been interpolated.

OVERTURNING AND CIRCULATION OF THE WATER.

The Finger Lakes belong to the temperate type, in which the water is subject to an overturning and a complete vertical circulation in the autumn and also in the spring. These phenomena are such important factors in the general distribution of the dissolved gases that they deserve a brief description here as a preliminary to the discussion of the gases. When the surface water begins to cool in late summer or early autumn, it becomes heavier than the water below it and tends to sink, thereby producing convection currents. Through the agency of these currents and the wind the water of the epilimnion is thoroughly mixed, and as the temperature of this stratum declines with the advance of the season more and more of the lower water becomes mixed with the upper; that is to say, there is a downward movement of the thermocline and the epilimnion becomes thicker at the expense of the hypolimnion. This process continues until the temperature of the epilimnion approaches that of the hypolimnion, when the whole body of water may be set into rotation by a strong wind. This phenomenon is known as the autumnal overturning, and it is followed by a complete circulation of the water, which continues until the lake becomes covered with ice. Seneca and Cayuga Lakes do not freeze over completely very often—on an average only about once in 20 years—so that their waters are subject to disturbance by the wind during the entire winter.

As long as the temperature of the water remains above 4° in the autumn both the wind and the convection currents are concerned in the production of the circulation,

^a Birge, Edward A., and Juday, Chancey: The Inland Lakes of Wisconsin: The dissolved gases of the water and their biological significance. Wisconsin Geological and Natural History Survey, Bulletin xxii, Scientific Series No. 7, 259 p. 1911.

^b Fox, Charles J. J.: On the coefficients of absorption of the atmospheric gases in distilled water and sea water. Part I. Nitrogen and Oxygen. Conseil Permanent International pour L'Exploration de la Mer. Publications de circonstance, No. 41, 1907, 23 p., 1 pl.

but below that temperature the former is the only active agent. When the surface water cools below 4° it becomes lighter than the warmer water beneath it and tends to float on the latter; that is, there is a resistance to mixture owing to the difference in their temperatures. As a result, it requires a strong wind to disturb the water to any considerable depth. But in spite of this resistance to mixture the wind is able to disturb the water at all depths, even in the deepest lakes, and cause the late autumn and winter temperatures to fall well below 4° . (See table iv, p. 555.) The winter stratification is inverse; that is, the coldest water is at the surface and the warmest at the bottom.

In spring conditions again become favorable for an overturning and circulation of the water. In the lakes which freeze over in winter a preliminary step in this process is the removal of the covering of ice. Substantially all of the direct warming takes place close to the surface, and as the temperature rises this water becomes heavier than that below and tends to sink, thus producing convection currents; but this holds true only as long as the temperature remains below 4° or the point of maximum density. After the whole body of water reaches a temperature of 4° any warming of the surface layer makes it lighter than the cooler water below and it tends to float on the latter. This eliminates convection currents as a factor in producing a general circulation, but they still play a more or less important rôle in mixing the water of the upper stratum when cooling takes place at the surface at night or during cool periods. The wind is now the only agent involved in the production of a complete vertical circulation.

As the season advances the temperature of the upper water rises so that it offers a greater and greater resistance to mixture with the cooler water below. As a consequence the tendency of the lower water to take part in the circulation grows correspondingly smaller and smaller. Finally the thermal resistance to mixture becomes so great that the wind is no longer able to mix the warm upper water with the cooler water below and the lake becomes separated into three distinct strata, viz, the epilimnion, the thermocline, and the hypolimnion. (See p. 547.) This is known as a direct thermal stratification, and it persists from early summer until the autumnal overturn takes place.

The autumnal circulation is much more thorough than the vernal. This is due to the fact that the mere cooling of the water in the autumn, as long as its temperature is above 4° , produces convection currents which tend to mix the various strata. In the spring, however, general convection currents are formed only as long as the water remains below 4° , which is generally only a comparatively short period of time. Small, spring-fed lakes, in fact, in which the temperature of the bottom water rises to 4° before the ice disappears, and which are well sheltered from winds, may not experience a complete vernal overturning under favorable weather conditions.

OXYGEN.

Circulation periods.—During the autumnal and vernal periods of vertical circulation all of the dissolved gases, as well as other substances that may be held in solution, are uniformly distributed from surface to bottom; but during the succeeding stages there

may be marked changes in the gaseous content of the different strata. As the water cools in the autumn its capacity for oxygen increases, and free exposure to the air enables it to obtain additional amounts of this gas as circulation proceeds. As a result, the lakes enter the winter stage of their cycle substantially saturated with oxygen at all depths; that is, with about 9.0 cc. to 10.0 cc. per liter of water. No winter observations were made on the Finger Lakes, but it is safe to assume from the results obtained on Wisconsin lakes that there is little change in the quantity of oxygen in the deeper lakes during the winter, more especially in those which show only a comparatively small decrease in the lower water in summer. In winter the life processes which furnish decomposable material are at a low ebb, and the temperature of the water is so low that decomposition goes on very slowly, even at the bottom, where organic material may be fairly abundant. In the shallower lakes, however, there may be a marked decrease of dissolved oxygen in the bottom stratum, and under favorable conditions it may even disappear entirely from some of the lower water.

At the close of the vernal period of vertical circulation the oxygen has a fairly uniform distribution from surface to bottom, but more or less marked changes take place in the different strata during the direct stratification stage, so that the history of the dissolved gases is different for the different zones. The maximum difference is found during August, and for this reason a single set of observations during this month, such as made on the Finger Lakes, makes it possible to give the history of the dissolved gases with a very considerable degree of accuracy for the whole stratification period.

In the epilimnion.—As already noted, the epilimnion is kept in circulation by the wind, which tends to keep the quantity of dissolved oxygen near the saturation point. But the amount is subject to variations in spite of this fact. As the temperature of the epilimnion rises in spring and early summer its capacity for holding oxygen in solution decreases so that the volume of this gas tends to decrease until the summer maximum of temperature is reached. But the loss of oxygen may not keep pace with the rise in temperature. That is, a certain quantity in excess of the amount required for saturation may remain for a while, since the water tends to retain the residual gas unless it is pretty thoroughly agitated by the wind. In such instances, however, the quantity of excess oxygen is never very great. This stratum is preeminently the zone of photosynthesis and in this process some oxygen is liberated by chlorophyllous organisms. If the epilimnion is well populated with such organisms and the conditions are favorable for photosynthesis this stratum may become supersaturated with the oxygen that is liberated. Another small amount is obtained from the nitrites and nitrates which serve as a source of nitrogen for the chlorophyllous organisms.

The appended table (table xviii, p. 602) shows that at the time of these observations the epilimnion of all of the Finger Lakes contained between 6 and 7.4 cc. of dissolved oxygen; with the exception of Conesus Lake it was a little larger than the amount required for saturation, the maximum excess being about 12 per cent. In most of the lakes a larger portion or perhaps all of this excess oxygen was most probably due to the photosynthetic activities of chlorophyl-bearing organisms since they were well

populated with such forms. But in some of the larger and deeper lakes a portion or possibly all of the excess may have been due to the presence of residual gas, more especially since some of them, such as Owasco and Seneca, had a relatively small number of chlorophyllaceous organisms.

In addition to the processes which tend to keep the volume of oxygen at or above saturation in this stratum, there are others which tend to reduce it below that point. A certain amount is consumed in the respiration of the various organisms inhabiting this region, and another portion, perhaps much larger, is removed by the decomposition of organic material. The amount of oxygen actually held in solution by this water then is the resultant of the processes which tend to maintain an abundant supply and those which tend to exhaust it. If consumption exceeds the new supply, the amount falls below the saturation point as in Conesus Lake; but if the factors which tend to maintain saturation and to raise the amount above this point predominate, the opposite result is produced.

In the hypolimnion.—During the period of thermal stratification, the hypolimnion is cut off from contact with the air by the epilimnion and conditions are not favorable for photosynthesis in this stratum. As a result the only source of oxygen during this time is the small amount which diffuses down from the upper water. But this gas diffuses very slowly through water, its coefficient of diffusion being only 1.62, so that only a small and negligible amount is obtained in this way. Thus the supply of dissolved oxygen of the lower water is limited to the amount which it possesses at the close of the vernal period of circulation. Any decrease during the summer remains as a deficiency until the autumnal overturn takes place and the normal amount is not regained until after complete autumnal circulation is established.

As might be expected from the above conditions, different lakes show wide differences with respect to the quantity of dissolved oxygen in the hypolimnion in late summer; but they readily fall into three groups. The first includes those lakes in which some or practically all of the hypolimnion is devoid of free oxygen in the later stage of the stratification period; the second comprises those lakes in which there is a marked decrease of dissolved oxygen in some or all of the hypolimnion but not an actual disappearance of it; and the third class includes those lakes in which the decrease of the oxygen in this stratum is comparatively slight. These differences in the dissolved oxygen content depend, in the main, upon two factors, viz, the amount of decomposition taking place in the hypolimnion (which may be characterized as the zone of decomposition) and upon the volume of this stratum. If the epilimnion contributes a large amount of decomposable material in the form of dead plankton organisms to the lower water and the volume of the hypolimnion is relatively small, most or practically all of the dissolved oxygen in the stratum may be consumed before the autumnal overturning. Before the oxygen all disappears, some of it is also consumed in the respiration of organisms which may occupy this region, such for example as fishes and plankton crustacea. But decomposition is a much more important factor in the removal of oxygen from this stratum.

Conesus and Otisco Lakes are good representatives of this class. In the former all of the water below a depth of 10 meters either possessed no free oxygen at all or contained only traces of it. The same was true of a few meters of the bottom water of Otisco Lake. (See table XVIII, p. 602, fig. 9 and 10.) The oxygen disappears from the bottom water first because decomposable material is more abundant at that depth. This material is derived from plankton organisms and from shallow water and shore vegetation. The specific gravity of the plankton organisms is so low that they sink

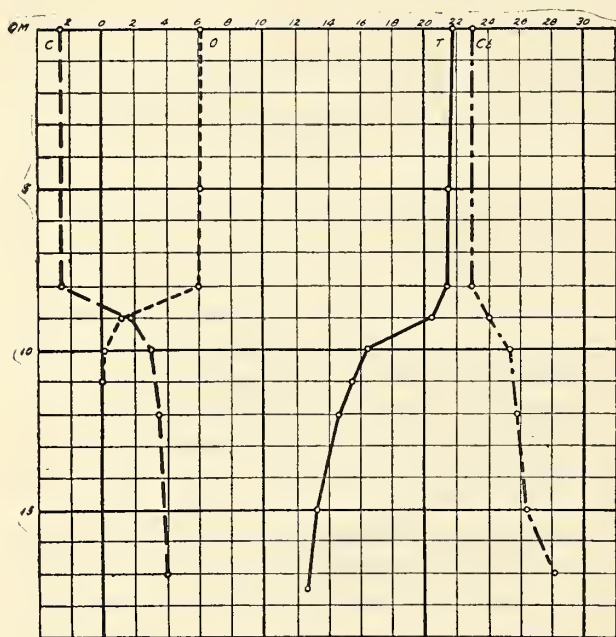


FIG. 9.—Conesus Lake, Aug. 25, 1910. The curves for dissolved gases are designated as follows: C=carbon dioxide; that portion to the left of the zero line indicates the alkalinity and that to the right the free carbon dioxide; Cb=fixed carbon dioxide; O=oxygen; and T=temperature. The vertical spaces represent the depth in meters and the horizontal spaces show the temperature in degrees centigrade and the cubic centimeters of gas per liter of water at normal temperature and pressure. The depths at which observations were made are indicated by small circles and these points have been connected directly without any attempt to round off the curves.

through the cool, lower water very slowly and they thus pass through the earlier stages of decomposition at least before they reach the bottom. In this way they draw upon the oxygen supply at all depths in the hypolimnion so that, if such decomposing organisms are sufficiently numerous and the volume of this stratum is not too great, practically all of the dissolved oxygen may disappear from this region.

If the decomposable material derived from the epilimnion is not so abundant, or if the volume of the hypolimnion is relatively great, with a correspondingly large amount of oxygen, there is not a total exhaustion of this gas in any of this stratum, but only a marked decrease, such as was noted in Canadice and Hemlock Lakes. (See table XVIII, p. 602, and fig. 11 and 12.) Here the water below 18 meters contained less

than 50 per cent of the quantity of oxygen required for saturation; the bottom water in the latter lake had as little as 8.4 per cent. If a still smaller quantity of decomposable material is derived from the upper water, or if the volume of the hypolimnion is still larger, the decrease of oxygen is correspondingly smaller, as in Canandaigua, Cayuga, Keuka, Owasco, Seneca, and Skaneateles Lakes, which belong to the third class. (Table XVIII, p. 602, and fig. 13–18.) Perhaps Keuka Lake should be placed in the second class, since its bottom water contained less than two-thirds of the amount of oxygen required for saturation; but it

has been placed in the third class because it belongs to the group of major lakes in other features.

The minimum amount of oxygen in these lakes was found at the bottom, and it varied from 5.57 cc. per liter of water in Keuka Lake to 8.45 cc. in Seneca Lake, or from 63.8 to 91.7 per cent of saturation. It will be noted that all of the members of this class are the larger and deeper lakes of the group—that is, those that have been designated as the major lakes. The volume of the hypolimnion of each is relatively large in comparison with the epilimnion, very large indeed in the deepest ones, and this large body of cool water is able to hold in solution a proportionally large quantity of oxygen, so large that the respiration of the organisms inhabiting it and the decomposition of the organic material which sinks into it from the upper water do not make extensive inroads upon the supply of free oxygen. The members of the first and second classes constitute the group of minor lakes. They are relatively small and shallow bodies of water, in which the volume of the epilimnion is large in proportion to that of the hypolimnion.

How large a proportion of the oxygen supply of the hypolimnion is lost during the summer depends upon the amount consumed in respiration and decomposition and upon the volume of this stratum. If the volume of the epilimnion is relatively large in proportion to that of the hypolimnion and it is well populated with plankton organisms, so that it contributes a large amount of decomposable material to the latter, the dissolved oxygen is rapidly consumed, so that very little may be left in this stratum by midsummer. On the other hand, when the hypolimnion is relatively very large and the upper water contributes only a comparatively small amount of decomposable material, the total volume of oxygen suffers only a very small decrease.

In the thermocline.—The quantity of dissolved oxygen in the thermocline is dependent in the main upon the amount in the hypolimnion. If it is practically exhausted from the lower water, there is generally a rapid decrease of oxygen as we pass downward through the thermocline. In Conesus Lake, for example, the amount decreased from 6.0 cc. per liter of water at 8 meters to 0.11 cc. at 10 meters. In Otisco Lake it declined from 5.77 cc. at 9 meters to 0.34 cc. at 12 meters. (See table XVIII, p. 602.) But lakes

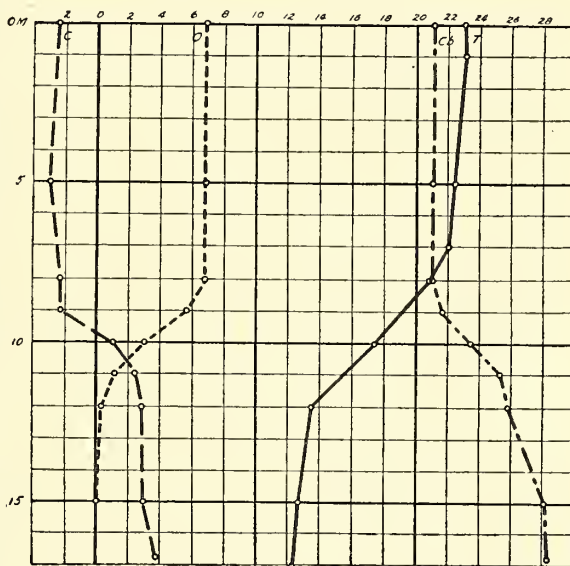


FIG. 10.—Dissolved gases, Otisco Lake, Aug. 16, 1910. For explanation, see fig. 9, p. 580.

belonging to this class may have a large excess of oxygen in the thermocline; as much as 20.0 cc. per liter or more have been found in some of the small lakes of Wisconsin.

In lakes of the second class there may be either an appreciable decrease of oxygen in the thermocline, as in Green Lake, Wis., or the amount may be larger than that found in the epilimnion or the hypolimnion, as in Canadice and Hemlock Lakes. The oxygen curves of the latter lakes (fig. 11 and 12) show that the maximum amount of

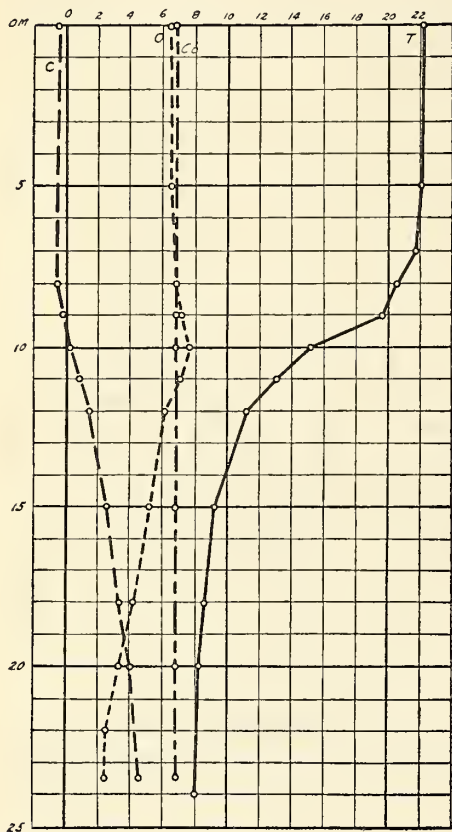


FIG. 11.—Dissolved gases, Canadice Lake, Aug. 24, 1910.
For explanation, see fig. 9, p. 580.

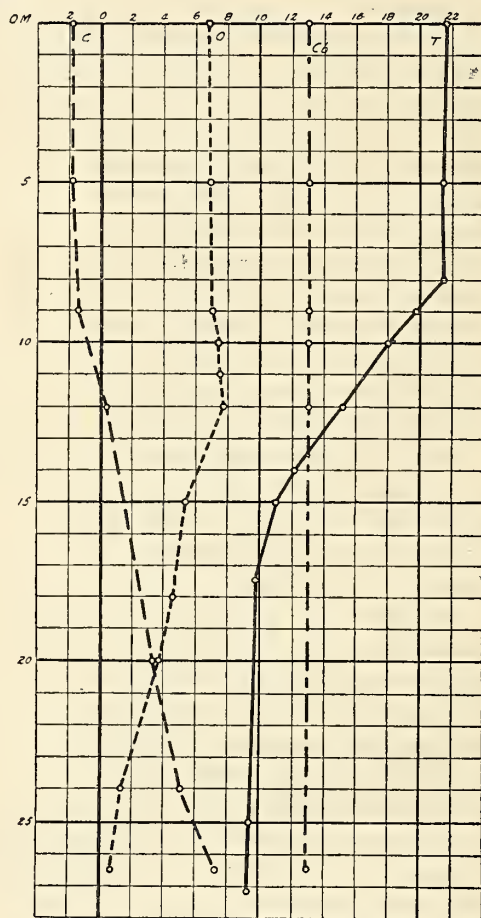


FIG. 12.—Dissolved gases, Hemlock Lake, Aug. 23, 1910.
For explanation see fig. 9, p. 580.

this gas was obtained in the thermocline, a small excess being present there. This increased quantity doubtless represented oxygen that had been liberated in this stratum by chlorophyllaceous organisms.

In the third class of lakes there was a larger quantity of oxygen in the thermocline than in the epilimnion, owing to the fact that this water was cooler, hence capable of holding a larger amount in solution. (See fig. 13-18.)

CARBON DIOXIDE.

Carbon dioxide is readily soluble in water, but the total amount that may be found in a lake water depends chiefly upon the quantity of other substances present with which it is most generally combined. It exists in three different states. A part of it is in close chemical union with substances that are dissolved in the water, more especially calcium and magnesium, forming the carbonates of these substances. This is known as the fixed carbon dioxide. Another is in a fairly loose combination with the carbonates, converting them into bicarbonates. This constitutes the half-bound carbon dioxide. A third portion exists in an uncombined or free state, and is known as the free carbon dioxide.

Fixed carbon dioxide.—The quantity of fixed as well as of half-bound carbon dioxide depends upon the amount of calcium and magnesium that may be present in the water, and the amount of these substances, in turn, is dependent upon their relative abundance in the drainage basin. The normal carbonates of calcium and magnesium are only slightly soluble in pure water. Rainwater absorbs carbon dioxide from the air, and obtains still more from decomposing organic matter when it reaches the earth. When this water, which is charged with more or less free carbon dioxide, comes into contact with these normal carbonates, they are freely converted into bicarbonates, which readily pass into solution. Thus, if the water which falls upon the adjacent land and reaches the lake either by surface drainage or by percolating through the ground and finally emerging as a spring, comes into contact with an abundance of calcium and magnesium carbonates on its journey, the lake water will possess a relatively large amount of bicarbonates, and it will be classed as "hard" water. If, however, the inflowing water comes into contact with very small amounts of these normal carbonates, the quantity of bicarbonates will be small, hence the lake water will be "soft."

This serves to explain why there is such a marked difference in the quantity of fixed carbon dioxide in the waters of the Finger Lakes. It varied from a minimum of 6.8 cc. per liter of water in Canadice Lake to 24.0 cc. in Canandaigua Lake. (See table XVIII, p. 602, and fig. 9–18.) In Hemlock Lake the fixed carbon dioxide amounted to 12.9 cc.,

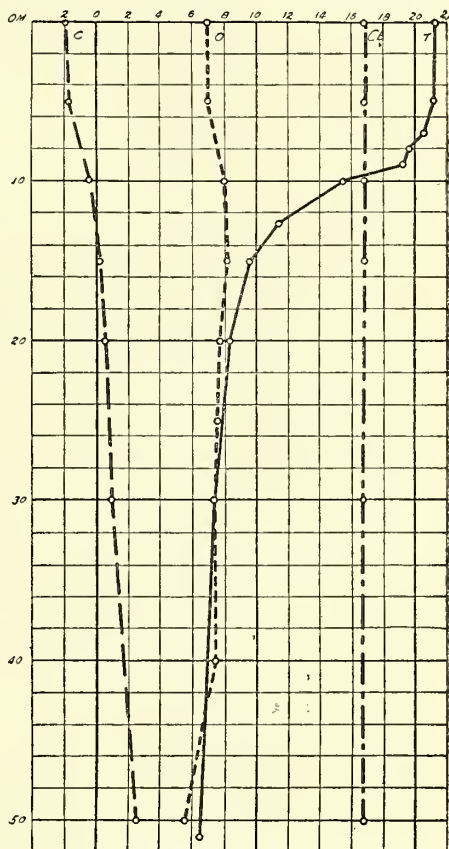


FIG. 13.—Dissolved gases, Keuka Lake, Aug. 18, 1910.
For explanation see fig. 9, p. 580.

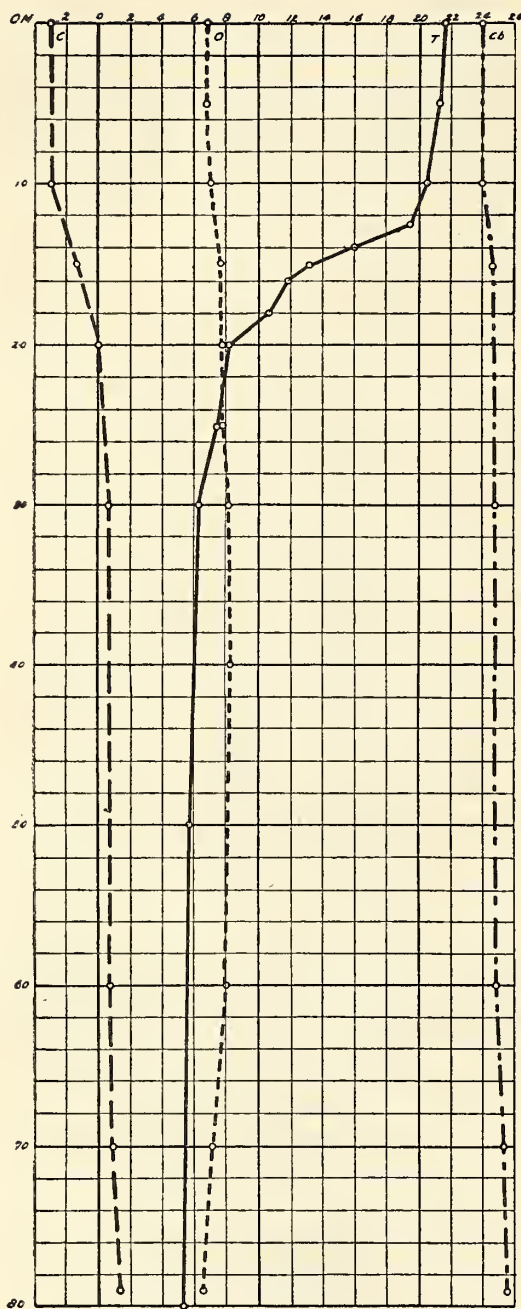


FIG. 14.—Dissolved gases, Canandaigua Lake, Aug. 20, 1910.
For explanation see fig. 9, p. 580.

in Keuka Lake, 16.8 cc., while in the other lakes it varied from 21.0 to 24.0 cc. In Conesus and Otisco Lakes there was an appreciable increase of this gas toward the bottom; in the former the bottom water contained 5.1 cc. more than the surface and in the latter 7.3 cc.

A much greater range in the quantity of fixed carbon dioxide has been found in the waters of the Wisconsin lakes. In them the amount varies from a minimum of 1.0 cc. to a maximum of about 50.0 cc.

Half-bound carbon dioxide.—In neutral waters and in those which possess free carbon dioxide the half-bound carbon dioxide is assumed to be equal in amount to the fixed. But in waters which give an alkaline reaction with phenolphthalein there is an excess of fixed carbon dioxide which equals in amount the deficiency of the half-bound. From a biological standpoint the half-bound carbon dioxide is of very great importance since it serves as a source of carbon dioxide for the photosynthetic activities of chlorophyllous organisms. From four-fifths to five-sixths of it may be consumed in this process, but none of the fixed carbon dioxide is available. The free carbon dioxide may be consumed by the algæ, but if found at all in the upper water it is present very generally in relatively small amounts.

Free carbon dioxide.—There are four sources of free carbon dioxide in lake waters. They are the atmosphere, decomposition of organic material, the respiration of organisms, and spring or ground waters. This gas constitutes a small portion of the atmosphere, from three to four parts per 10,000, so that where a water is freely exposed to the

air it will be found to contain some free carbon dioxide. The amount, however, is small because it is absorbed only in proportion to its partial pressure. The decay of organic matter yields considerable carbon dioxide and, under favorable conditions, the water may become charged with fairly large amounts derived from this source. This is true especially of the bottom water. Spring waters are generally charged with free carbon dioxide, so that they contribute their quota.

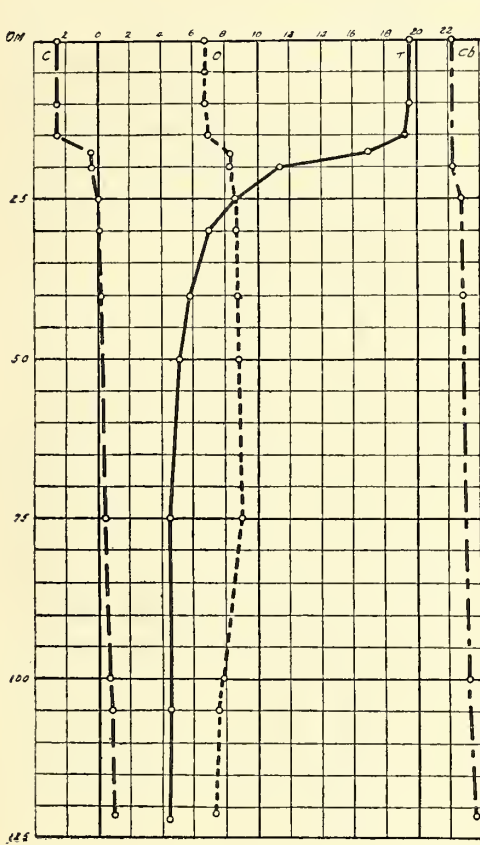


FIG. 15.—Dissolved gases, Cayuga Lake, Aug. 11, 1910. For explanation see fig. 9, p. 580.

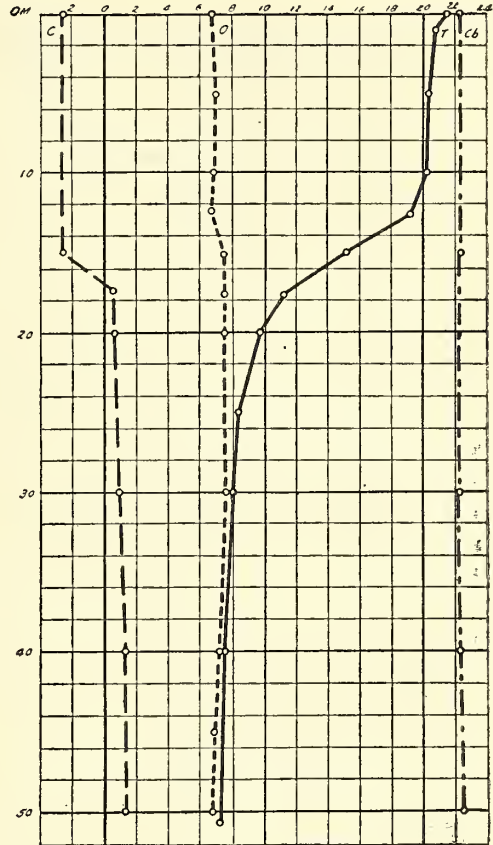


FIG. 16.—Dissolved gases, Owasco Lake, Aug. 13, 1910. For explanation see fig. 9, p. 580.

The quantity of free carbon dioxide in the epilimnion is subject to variations. The water of this stratum is kept in circulation by the wind and this process tends to maintain a normal amount of this gas; but the quantity derived from the respiration and the decomposition which take place in this layer tends to raise it above the saturation point. On the other hand, this region is preeminently the zone of photosynthesis and in this process carbon dioxide is consumed and oxygen is liberated. When this stratum is fairly well stocked with chlorophyllous organisms and conditions are

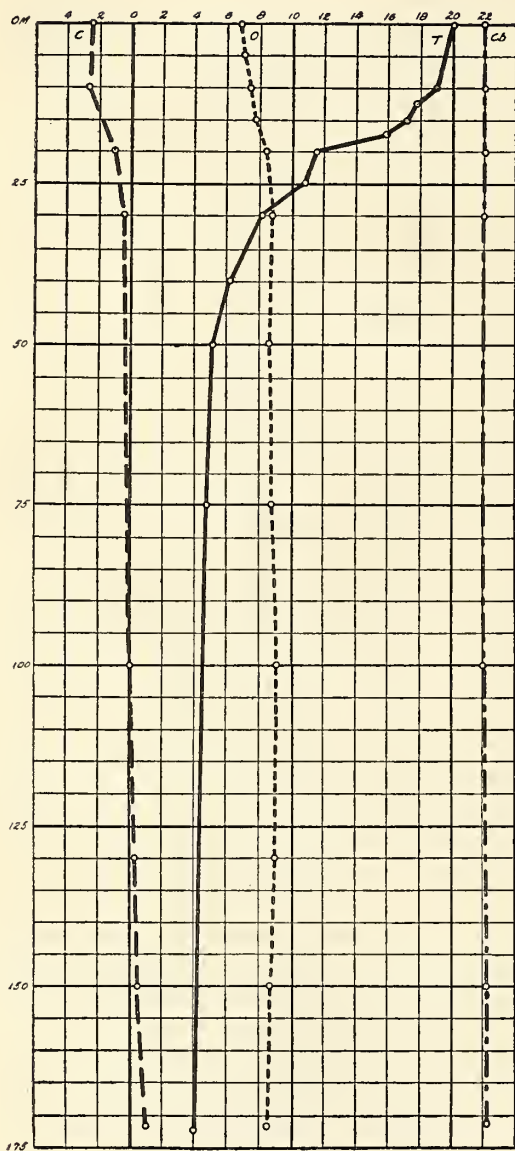


FIG. 17.—Dissolved gases, Seneca Lake, Aug. 4, 1910. For explanation see fig. 9, p. 580.

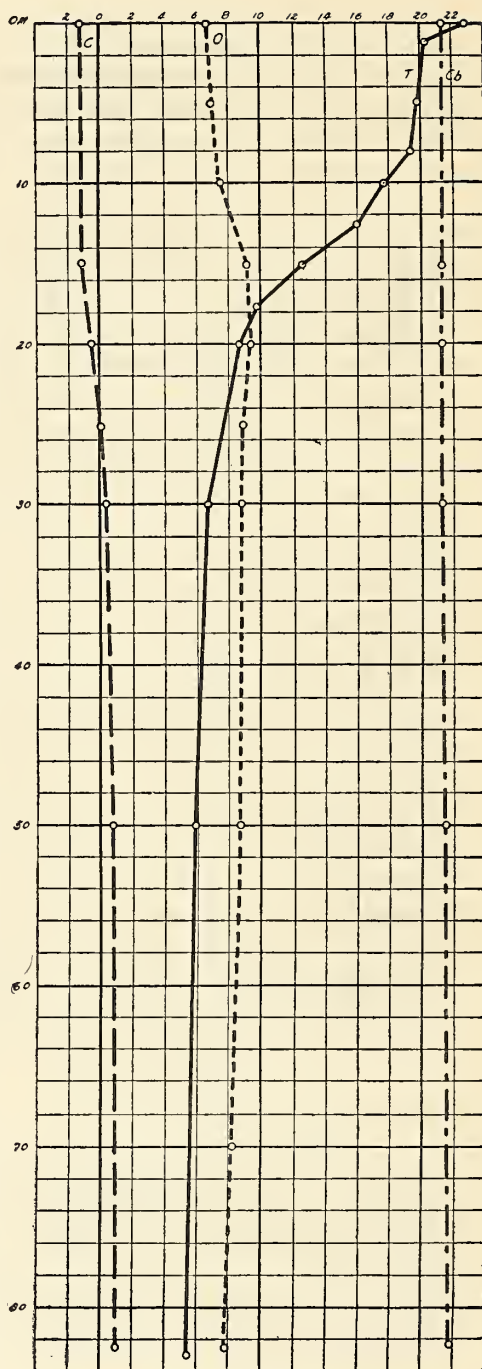


FIG. 18.—Dissolved gases, Skaneateles Lake, Aug. 15, 1910. For explanation see fig. 9, p. 580.

favorable for their activities, the demand for carbon dioxide exceeds the supply of free gas and some of the half-bound carbon dioxide is consumed. This makes the water alkaline to phenolphthalein, since it leaves an excess of normal carbonate. The degree of alkalinity is measured by the amount of carbon dioxide that would be required to convert this normal carbonate to bicarbonate, and it is dependent upon several factors, chief among which are the free exposure to the atmosphere, decomposition, respiration, the abundance and activity of the algæ, and the weather conditions. Thus it will be seen that the status of the carbon dioxide in the epilimnion is the resultant of the activities of those agents which furnish a supply to this stratum and those which consume this gas.

The epilimnion in all of the Finger Lakes was alkaline, thus showing that not only the free, but also some of the half-bound carbon dioxide, had been consumed by the chlorophyll-bearing organisms. (See table XVIII, p. 602, and fig. 9-18.) The degree of alkalinity varied in the different lakes, ranging from a minimum of about 0.5 cc. in Canadice Lake to a maximum of 3.0 cc. in Canandaigua Lake; in five lakes the average amount was about 2.5 cc. In the carbon dioxide curves the alkaline stratum is indicated by that portion which lies to the left of the zero line and the degree of alkalinity is shown by the quantity of carbon dioxide required to make the water neutral.

The free carbon dioxide content of the thermocline depends upon the conditions which are found there for photosynthesis. In some lakes this stratum lies so near the surface that light conditions are favorable for this process and in such cases not only the free, but a large portion of the half-bound carbon dioxide may be removed by chlorophyllous organisms, thus making the stratum strongly alkaline. But in a large majority of cases conditions in this stratum are not favorable for photosynthesis and the water contains free carbon dioxide. This was true of all of the Finger Lakes.

The hypolimnion is a zone of decomposition, so that its water generally contains an abundance of free carbon dioxide. In the process of respiration also a certain amount of this gas is contributed to the water and some may reach this stratum from underground waters. The largest amount is found at the bottom of the lake, where decomposition is greatest owing to the presence of a large amount of organic material. The maximum quantity found in the bottom waters of the Finger Lakes varied from 1.0 cc. per liter in Cayuga Lake to 7.1 cc. in Hemlock Lake.

PLANKTON.

Methods of observation.—Plankton catches were obtained in the Finger Lakes at the same time that samples of water were procured. They were made either by means of a pump and hose or with a vertical closing net. The former method was used at all depths in Canadice, Conesus, and Hemlock Lakes, and in the upper 30 meters and 50 meters, respectively, of Cayuga and Seneca Lakes, while the latter method was employed below these depths in the last two lakes and at all depths in the other five lakes. For the purpose of counting, a catch was diluted to 10 cc., of which 2 cc. were removed with a "stempel" pipette, and the crustacea and rotifers therein were counted. When

only a small number of the larger crustacea were present, the total number in the catch was determined by direct count. One cubic centimeter of the diluted material was then placed in a Sedgwick-Rafter counting cell, and the protozoa and algæ were enumerated in the usual manner. The results were reduced to the number of individuals per liter of water, and the diagrams were platted on this basis. For table XIX the number of planktons per liter was multiplied by a thousand in order to give the number per cubic meter of water.

Distribution of plankton organisms.—The vertical distribution of the various plankton organisms in the five lakes on which pump catches were made is shown in the accom-

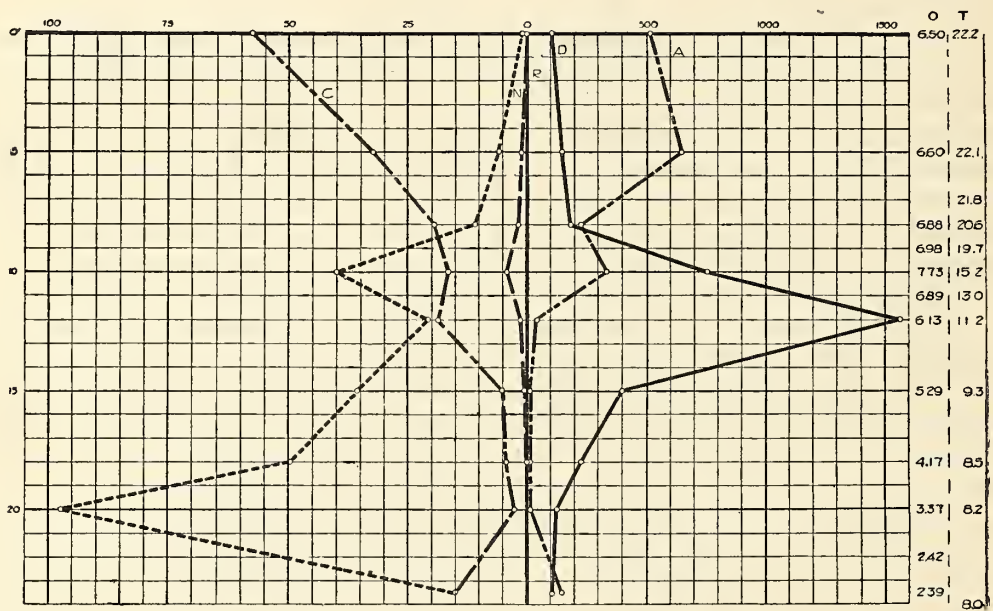


FIG. 19.—Vertical distribution of plankton organisms in Canadice Lake, Aug. 24, 1910. Scale, 1 vertical space=1 meter; 1 horizontal space=5 crustacea, nauplii, and rotifers, and 100 algæ and diatoms per liter of water. Predominant forms: *Cyclops*, *Diaptomus*, *Ceratium*, and *Asterionella*. The column at the right marked O shows the quantity of dissolved oxygen at the various depths as indicated, and T represents the temperature.

panying diagrams (fig. 19-23). These figures show the usual distribution of the chlorophyll-bearing portion of the plankton. That is, such organisms are confined chiefly to the epilimnion, where light conditions are most favorable for their photosynthetic activities. So much of the sun's energy is absorbed by the upper meters of water that only a very small portion generally penetrates as far as the thermocline and the hypolimnion, thus making these regions unfavorable for the forms which depend upon light for the manufacture of an important element of their food. But in some of the small lakes of Wisconsin, which are well protected from wind, the top of the thermocline lies at such a slight depth—only 3 to 4 meters below the surface—that enough light for the process of photosynthesis reaches this stratum. This is shown by the large excess of oxygen that is sometimes found in this layer.

Some of the plankton algæ appear to be able to live saprophytically, and such forms could maintain themselves in this manner in the deeper water. *Oscillatoria* seems to show this tendency most frequently, and one of its usual distributions was shown in Keuka Lake, where the maximum number was found in the 15–20 meter stratum. (See table XIX, p. 606.) In general, however, the presence of large numbers of phytoplankton below the thermocline is to be regarded as an indication of their senility.

The curves for zooplankton show two general types of vertical distribution. In one type the lower, as well as the upper, strata of the lake are well populated, as in Canadice and Hemlock Lakes (fig. 18, 19). A similar distribution was noted also in Keuka and

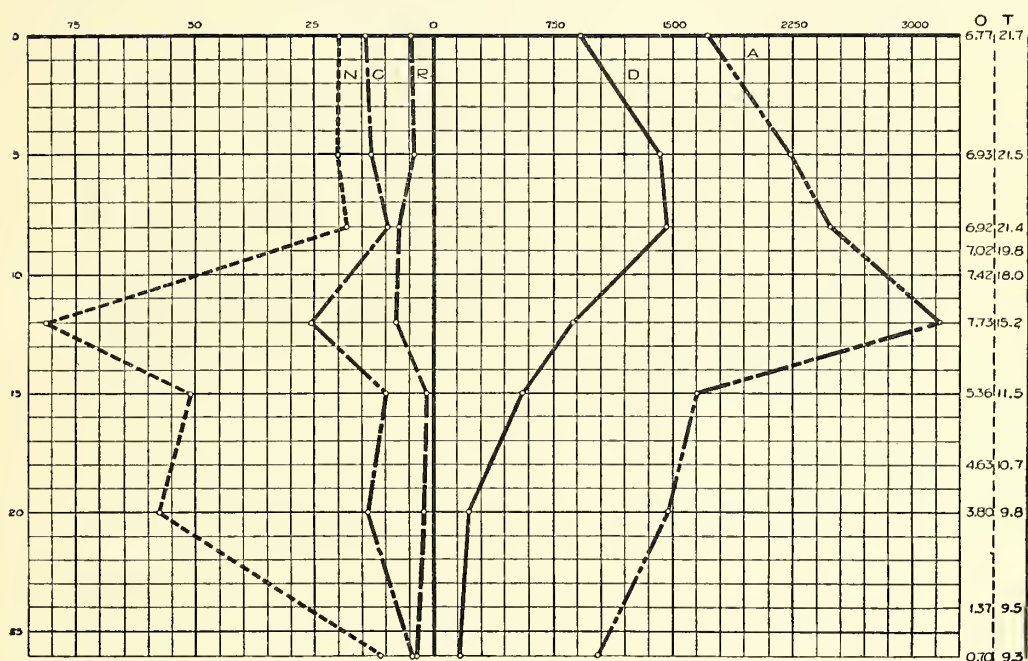


FIG. 20.—Vertical distribution of plankton organisms in Hemlock Lake, Aug. 23, 1910. Scale, 1 vertical space=1 meter; 1 horizontal space=5 crustacea, nauplii, and rotifers per liter of water and 150 algæ and diatoms. Predominant forms: *Diaptomus*, *Ceratum*, *Coelosphaerium*, and *Asterionella*. The column at the right marked O shows the quantity of dissolved oxygen at the various depths as indicated, and T represents the temperature.

Owasco Lakes. All of the various forms of plankton animals were not distributed throughout the depth of these lakes, since some of them habitually occupy the warmer water of the epilimnion, while others are confined chiefly to the thermocline and the hypolimnion. In the latter stratum the crustacean population consisted almost entirely of *Diaptomus* and *Cyclops* and their nauplii, while *Polyarthra platyptera* had the widest vertical distribution among the rotifers. In general, the forms which have a wide vertical distribution reach their maximum numbers either in the upper or the middle strata of the lake. The presence of a fairly large population in the lower water is dependent upon two factors, viz, an adequate amount of both dissolved oxygen and food

in this region. Whenever the quantity of either falls below a certain amount, it affects the distribution of the organisms.

The second type of vertical distribution is characterized either by a very sparse population in a certain portion of the hypolimnion or by practically none at all. This is due either to a lack of dissolved oxygen or to a scarcity of food. In Conesus and Otisco Lakes, for example, the absence of organisms in the lower strata was caused by a lack of oxygen. (See fig. 20.) Results obtained on Wisconsin lakes show that the various zooplankton forms are capable of occupying water which has only a very small amount of dissolved oxygen, but a certain minimum quantity is necessary. The Cladocera and *Diaptomi* are only rarely found in water which has less than 0.2 to 0.3 cc. per liter, while the minimum for *Cyclops* and nauplii is about 0.1 cc., and for rotifers from

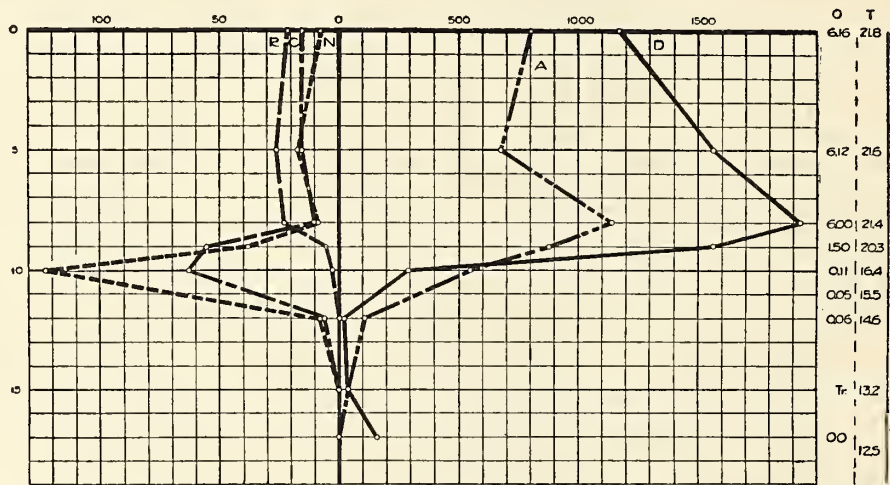


FIG. 21.—Vertical distribution of plankton organisms in Conesus Lake, Aug. 25, 1910. Scale, 1 vertical space=1 meter; 1 horizontal space=10 crustacea, nauplii, and rotifers per liter of water and 100 algæ and diatoms. Predominant forms: *Cyclops*, *Polarthra*, *Ceratum*, *Celosphaerium*, *Fragilaria*. The column at the right marked O shows the quantity of dissolved oxygen at the various depths as indicated, and T represents the temperature.

0.1 to 0.2 cc. Several forms, however, such as *Corethra* larvæ, an ostracod, and a number of protozoa are able to live in water which contains no trace of free oxygen; but all of the limnetic zooplanktons, except larval *Corethra*, require at least a small amount of this gas in a free state.

In Conesus Lake the maximum number of *Diaptomi* was found at 9 meters, where the water contained 1.5 cc. of oxygen per liter. *Cyclops* and the nauplii reached their maximum numbers at a depth of 10 meters, where this gas amounted to only 0.11 cc.; only a few remained at 12 meters, where the quantity of oxygen was only 0.06 cc., and none was found below this depth.

In Cayuga and Seneca Lakes (fig. 21 and 22) by far the larger portion of the hypolimnion had a very sparse population, being occupied by only a few crustacea, representatives of *Cyclops*, *Diaptomus*, and *Limnocalanus*, between 50 meters and the bottom.

But the bottom stratum was more densely populated, possessing a larger number of *Limnocalanus macrurus*, as well as a small population of *Mysis relicta*. A similar distribution of the crustacea in the lower water was found also in Canandaigua and Skaneateles Lakes.

The limiting factor in these lakes was not the lack of dissolved oxygen in the lower water, since there was an abundance of it even at the bottom, but it was a scarcity of food. The chlorophyl-bearing portion of the plankton is the primary source of food for the rotifers and the crustacea, either directly or indirectly, and, as noted above, these organisms are confined chiefly to the epilimnion. This means substantially that the

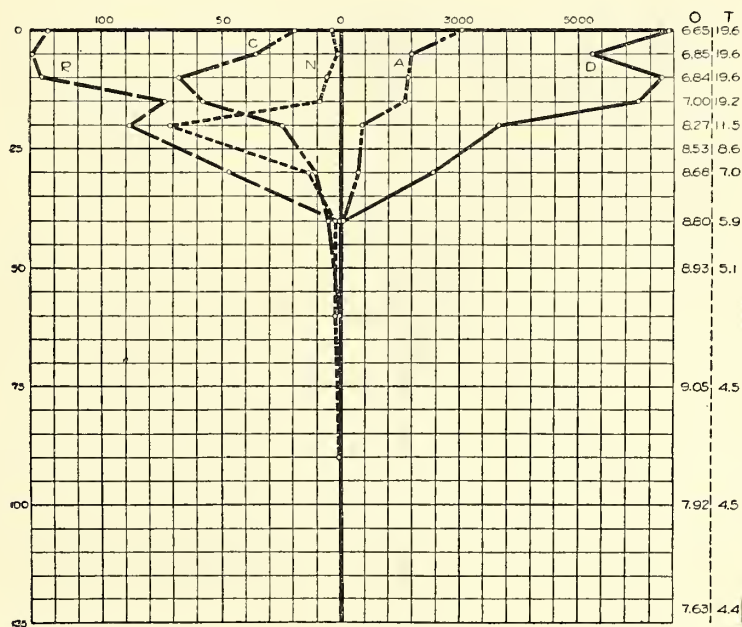


FIG. 22.—Vertical distribution of plankton organisms in Cayuga Lake, Aug. 12, 1910. Scale, 1 vertical space=5 meters; 1 horizontal space=10 crustacea, nauplii, and rotifers per liter of water and 600 algae and diatoms. Predominant forms: *Bosmina*, *Polysartha*, *Ceratium*, and *Asterionella*. The column at the right marked O shows the quantity of dissolved oxygen at the various depths as indicated, and T represents the temperature.

zooplankton, not only of the upper water, but also at all other depths, is dependent upon the food supply of the epilimnion. The zooplanktonts which occupy the epilimnion have the first choice of this food, and those in the hypolimnion must be content with that which reaches them from the upper water.

Granting that the lower water has an abundance of dissolved oxygen, the density of its population depends upon the food supply, which, in turn, is dependent upon the excess produced by the epilimnion and upon the volume of the hypolimnion. The excess of food produced by the upper water depends upon the productivity of that stratum and upon the amount consumed by the zooplankton therein. The largest excess of

course will be obtained from a large population of chlorophyll-bearing organisms and a small number of consumers. With a given amount of excess food the relative abundance depends upon the volume of the hypolimnion; the larger the volume of the water the smaller the relative abundance of food, and vice versa.

These two types of vertical distribution have been noted also in the Wisconsin lakes. Only a comparatively small number of these bodies of water show the first type of distribution. Among those showing the second type the scarcity or absence of rotifers and crustacea in the lower strata is due in all cases to the lack of oxygen, with the exception of Green Lake, in which an insufficient supply of food is the important factor.

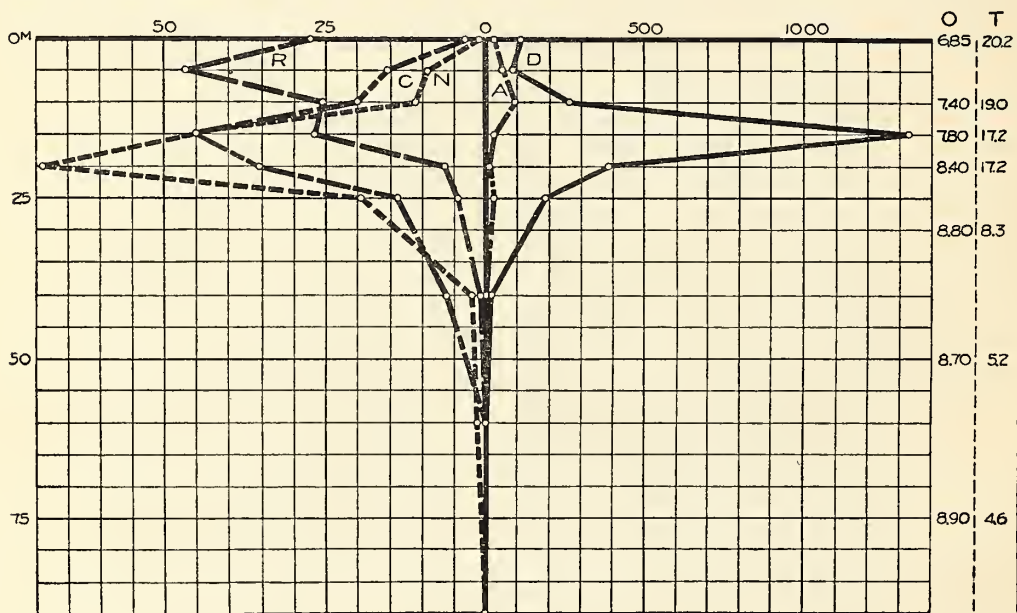


FIG. 23.—Vertical distribution of plankton organisms in Seneca Lake, Aug. 4, 1910. Scale, 1 vertical space=5 meters; 1 horizontal space=5 crustacea, nauplii, and rotifers per liter of water and 100 algae and diatoms. Predominant forms: *Cyclops*, *Polyarthra*, *Ceratum*, and *Asterionella*. Below 90 meters the organisms were too few to indicate in the diagram. The column at the right marked O shows the quantity of dissolved oxygen at the various depths as indicated, and T represents the temperature.

Taking into account the results obtained both on the Wisconsin lakes and on the Finger Lakes, it appears that when the hypolimnion is well populated the maximum depth of the lake does not exceed 40 to 50 meters. On the other hand, when the maximum depth reaches 70 meters or more a certain portion of the hypolimnion has a sparse population. The upper part of this stratum may possess a fairly large population, since it lies near the source of the food, and the bottom stratum may also be fairly well populated, but between these two regions lies a zone which is poor in zooplankton, owing to the scarcity of food. The thickness of this poorly populated zone depends upon the maximum depth of the lake and also upon the relative amount of food contributed to the hypolimnion by the upper water.

The Finger Lakes differ widely in area, depth, gas content, etc., but there was no corresponding qualitative difference in the plankton. For the most part the same forms were present in all of the lakes, but the relative abundance of the various forms varied greatly in the different lakes. The most prominent qualitative differences were the absence of *Daphnia* in Seneca Lake and the absence of *Limnocalanus* and *Mysis* in the smaller and shallower lakes.

Phytoplankton.—Three different classes of algæ were represented in the plankton of the Finger Lakes, viz, the Chlorophyceæ by *Staurastrum*; the Bacillariæ or diatoms by *Melosira*, *Cyclotella*, *Tabellaria*, *Fragilaria*, *Synedra*, *Asterionella*, and *Navicula*; and the Myxophyceæ, or blue-green algæ by *Anabaena*, *Aphanizomenon*, *Lyngbya*, *Oscillatoria*, *Cælosphærium*, *Clathrocystis*, *Gloeocapsa*, and *Aphanocapsa*. These forms were confined chiefly to the epilimnion where light conditions were most favorable for the process of photosynthesis. In some of the lakes, however, relatively large numbers of phytoplanktonts were found in the thermocline and even in the upper portion of the hypolimnion. In Cayuga Lake, for example, there were more than a thousand *Asterionellas* per liter of water at a depth of 30 meters and in Skaneateles Lake this same form numbered 1,161 per liter in the 30–50 meter stratum, more than five times as many as were found in the 0–10 meter stratum. The presence of this form in such large numbers in the deeper water where light conditions were not so favorable for photosynthesis was most probably due to the fact that they were senile individuals. Both lakes had a fairly high degree of transparency, a Secchi's disk disappearing from view at a depth of 5.1 meters in Cayuga Lake and at 10.3 meters in Skaneateles Lake, but it is doubtful whether enough light reached these organisms to enable them to carry on the process of photosynthesis to any considerable extent.

The circulation of the water of the epilimnion tends to produce a uniform distribution of the phytoplankton in this stratum, but the diagrams (fig. 18–22) indicate that such a result was not attained, since all of the curves representing algæ show a point of maximum density of population.

In Canandaigua and Otisco Lakes the blue-green algæ predominated, with *Clathrocystis* and *Cælosphærium* as the most abundant forms. *Clathrocystis* was the predominant alga in Owasco Lake. Diatoms were most abundant in the other seven lakes, with *Asterionella*, *Fragilaria*, and *Tabellaria* as the predominant forms.

Zooplankton.—*Ceratium* was found in all of the Finger Lakes, and was most abundant in Cayuga, where 2,525 individuals per liter of water were found at the surface. Hemlock Lake ranked second, with a maximum number of 1,645 individuals per liter at a depth of 12 meters. The smallest number was found in Owasco Lake, and Seneca Lake came next in order. Owing to the fact that this is a chlorophyllous organism, it has been included in the curves showing the blue-green algæ in the diagrams.

Dinobryon appeared in the plankton of 7 of the 10 lakes, but it was scarce in all except Owasco, where it was much more abundant than any of the other small organisms.

Mallomonas was found in three lakes, viz, Canadice, Conesus, and Otisco. In Canadice and Otisco Lakes it showed the peculiar distribution which has been noted by Whipple;^a that is, it was found only in a middle stratum in the lake. In the former lake it was found almost exclusively in the 10-15 meter stratum, only a few being at the bottom. There was a maximum number of 2,110 individuals per liter of water at 10 meters. In Otisco Lake it was confined to the 9-12 meter stratum, while in Conesus Lake it occupied only the epilimnion or 0-8 meter stratum.

Colonies of *Vorticella*, attached to colonies of *Anabaena* or some other alga, were found in small numbers in Canadice, Cayuga, Conesus, and Seneca Lakes. The largest number was noted in a surface catch from Cayuga Lake, 13 colonies per liter of water. In all of these lakes except Seneca, *Vorticella* was confined to the upper 10 meters or less, a few being noted at 15 meters in the latter lake.

Among the rotifers *Polyarthra* was the only form which was found in all of the lakes. It was most abundant in Cayuga Lake. One catch showed an average of 240 individuals per liter in the 0-5 meter stratum. Next in order were Seneca Lake, with an average of 23 individuals per liter in the upper 15 meters, and Conesus, with an average of 23 for the upper 8 meters. In all cases *Polyarthra* was more abundant in the epilimnion than below this stratum.

Anuraea cochlearis was present in all but three lakes, Conesus, Owasco, and Skaneateles. It was not as abundant as *Polyarthra*. The largest catch showed only 53 individuals per liter. This catch was obtained in Cayuga Lake at a depth of 20 meters. Seneca Lake was next in order, with a maximum number of 40 per liter of water at 5 meters in one evening catch. In all of the other lakes no catch showed more than 4 individuals per liter. In both Cayuga and Seneca Lakes *Anuraea cochlearis* was found chiefly in the upper 20 meters of water.

Asplanchna likewise was most abundant in Cayuga and Seneca Lakes. The maximum number of 26 individuals per liter of water was found at a depth of 5 meters in Cayuga Lake, while a catch at this same depth in Seneca Lake showed 15. A very few individuals were found in Keuka, Owasco, and Skaneateles Lakes, and none in the other lakes. It was confined chiefly to the epilimnion.

Notholca longispina was present in all of the lakes except Owasco and Skaneateles. The largest number, 4 per liter, was found at a depth of 12 meters in Hemlock Lake.

Conochilus was found in all except three lakes, Canadice, Conesus, and Otisco, but it was present in very small numbers and always in the epilimnion.

Anuraea aculeata appeared in the catches from five lakes, but its maximum number was less than 3 individuals per liter of water.

The catches from Cayuga and Seneca Lakes contained a few *Ploesoma*, the largest number being 6 per liter.

A few specimens of *Triarthra* were found in Cayuga, Hemlock, and Keuka Lakes.

In counting the copepods no attempt was made to enumerate the different species of *Diaptomus* and *Cyclops* separately. The former genus was represented in all of the

^a Whipple, G. C., *Microscopy of drinking water*, p. 109. New York, 1899.

lakes. Two species, *D. minutus* and *D. sicilis*, were found in Cayuga and Seneca Lakes, but only the former species was present in the other lakes. In its vertical distribution, *Diaptomus* was found at all depths where the water contained a sufficient amount of dissolved oxygen. In Conesus and Otisco Lakes it did not occupy the bottom water, owing to the absence of oxygen, but the maximum number in both was obtained just above the low oxygen zone. The largest number in Conesus Lake, 43 individuals per liter, was found at 9 meters where the water contained 1.5 cc. of oxygen, but the number fell below 1 per liter at 10 meters where the water contained only 0.11 cc. of free oxygen per liter. In Otisco Lake the largest number was found in the 9-12 meter stratum where the oxygen decreased from 5.8 cc. at 9 meters to 0.34 cc. at 12 meters.

The largest catch of *Diaptomus* was obtained at the surface of Canadice Lake, 48 individuals per liter. This was a rather unusual distribution, since this form usually avoids a few meters of the upper water in the daytime. The second largest catch was that on Conesus Lake, noted above. In Seneca Lake the maximum number, 20 per liter, was found at 50 meters. In both Seneca and Cayuga Lakes, *Diaptomus* showed a diurnal movement of about 10 meters.

Representatives of the genus *Cyclops* were found in all of the lakes. In Seneca and Cayuga Lakes this form was most abundant in the upper 50 meters, although it extended to the bottom. In some lakes, however, it was confined entirely to the upper water. In Canandaigua Lake it was not found below 15 meters; in Skaneateles Lake, not below the 20-30-meter stratum; and in Owasco Lake, not below the 10-15-meter layer. This was a rather unusual distribution, since in general *Cyclops* seems to experience no difficulty in occupying much deeper water than is found in these lakes. Their absence from the lower water was not due to a scarcity of dissolved oxygen, because there was an abundance of it in the bottom water of these lakes, in fact almost or quite as much as at the surface.

In Keuka Lake *Cyclops* was most abundant in the upper 10 meters, but in Canadice and Hemlock Lakes it was distributed rather uniformly from surface to bottom. In Conesus Lake its distribution was similar to that which has been found frequently in some of the Wisconsin lakes, viz, a fairly uniform distribution in the epilimnion with a maximum number in the thermocline, where there is a rapid decrease of the oxygen. The maximum number, 62 per liter, was found at 10 meters, where the dissolved oxygen amounted to only 0.11 cc. per liter. But in Otisco Lake, where there was also a rapid decrease of dissolved oxygen in the thermocline, no such phenomenon was found, there being a fairly uniform distribution in the epilimnion with only a small number below this stratum.

Limnocalanus in small numbers was found in five lakes—Cayuga, Seneca, Canandaigua, Skaneateles, and Owasco. It was confined to the hypolimnion, or lower stratum, of all of these lakes. A very few specimens of *Epischura* were obtained in Keuka and Owasco Lakes.

The copepod nauplii showed great diversity in their vertical distribution. They were found at all depths in the majority of the lakes, but they were more abundant

in the upper strata, say, in the upper 20 or 30 meters of the deeper lakes and in the upper 10 or 15 meters of the shallower ones. There was one marked exception to this. In Canadice Lake the maximum number was found at a depth of 20 meters, within 4 meters of the bottom. In Conesus and Otisco Lakes the distribution was similar to that which has been found in some of the Wisconsin lakes. That is, the maximum number was found in the thermocline, where there was only a small amount of dissolved oxygen. For example, there were 123 individuals per liter at a depth of 10 meters in Conesus Lake where the oxygen amounted to only 0.11 cc. per liter of water.

The cladoceran population of Seneca Lake was characterized by the absence of *Daphnia* and by the relative abundance of *Bosmina*. The latter occupied the upper 50 meters of water and the largest number, 31 individuals per liter, was found at a depth of 5 meters in an evening catch. The only other Cladocera represented in the plankton catches of Seneca Lake were *Ceriodaphnia* and *Polyphemus pediculus*, but only a very small number of each was found. *Daphnia* was absent from the regular plankton hauls on Cayuga Lake, but a few specimens of *D. hyalina* were found in one of the townet catches. *Bosmina* was found at all depths in Cayuga Lake, but it was most abundant in the upper 30 meters. The maximum number, 66 individuals per liter of water, was obtained in a morning catch at a depth of 10 meters. *Ceriodaphnia* and *Polyphemus pediculus* were also represented in the plankton of Cayuga Lake, but they were not noted in any other lakes.

Daphnia longispina var. *hyalina* was represented in all of the lakes except Seneca. It was confined chiefly to the epilimnion of the various lakes and was most abundant in Hemlock Lake. *Daphnia pulex* was present in Canadice and Conesus Lakes. It was scarce in the former but a little more abundant than *D. hyalina* in the latter.

A few *Daphnia retrocurva* were found in the 12-meter catch of Hemlock Lake.

Diaphanosoma was noted in Canadice, Canandaigua, Hemlock, Otisco, Owasco, and Skaneateles Lakes, and was confined to the epilimnion. It was most abundant in Canandaigua Lake, where it averaged about three individuals per liter in the upper 15 meters.

Bosmina was obtained in all of the lakes except Canadice, Conesus, and Otisco. It was most abundant in Cayuga Lake and Seneca came next. Only a relatively small number was obtained in the other five lakes.

A few specimens of *Leptodora hyalina* were found in each of the lakes except Conesus and Seneca.

Specimens of *Mysis relicta* were taken with townets in the lower water of Canandaigua, Cayuga, Keuka, and Seneca Lakes.

APPENDIX.—STATISTICAL TABLES.

HYDROGRAPHIC DETAILS OF THE NEW YORK LAKES.

In tables xv and xvi are given the details of the hydrography of the New York lakes. The figures are given both on the metric system and on the foot and mile system (table xvi). All measurements and all primary computations are made on the metric system. The areas given for the lake basins at 25 feet, 50 feet, etc., are derived not from replatting the soundings and drawing a new set of contours, but from the hypsographic curves constructed from the measurements on the metric system.

In the tables on the metric system columns 2-4 give the areas of the lake basin and the length of contours at the depths stated in column 1. In the subsequent columns the areas, volumes, and slopes are those between the depths stated in column 5.

Volumes are usually stated to tenths of a million cubic meters.

The formulas used in computation will be found on p. 538.

The general results of the hydrography are given in table 1, p. 537.

TABLE XV.—HYDROGRAPHIC DETAILS.

CANADICE LAKE

Depth.	Area.		Length of contours.	Depth.	Area.		Volume.		Slope.	
<i>Meters.</i>	<i>Sq. km.</i>	<i>Per cent.</i>	<i>Km.</i>	<i>Meters.</i>	<i>Sq. km.</i>	<i>Per cent.</i>	<i>Thousand cu. m.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>° '</i>
0	2.60	100.0	11.7	0-2.5	0.274	10.6	5,154	14.5	10.1	5 46
2.5	2.32	89.4	10.4	2.5-5	.144	5.5	5,632	13.2	17.0	10 09
5	2.18	83.0	10.1	5-10	.202	7.9	10,402	24.4	24.6	13 49
10	1.98	76.0	9.77	10-15	.345	13.2	9,034	21.2	14.0	7 59
15	1.63	62.8	8.62	15-20	.368	14.1	7,251	17.0	11.0	6 17
20	1.27	48.7	7.52	20-22.5	.329	12.7	2,753	6.5	5.37	3 04
22.5	.94	36.0	6.59	22.5-25.4	.936	36.0	1,351	3.2	1.45	0 50
25	.14	5.5	2.61							
25.4					2.60		42,577			

OTISCO LAKE.

[Measurements to causeway near south end.]

0	6.84	100.0	16.6	0-5	2.07	30.3	28,850	37.7	3.5	2 02
5	4.77	69.7	12.7	5-10	0.67	9.8	22,160	20.0	18.5	10 29
10	4.10	50.0	12.1	10-15	0.58	8.5	19,040	24.0	19.5	11 02
15	3.52	51.5	10.5	15-20.1	3.52	51.5	6,390	8.4	1.5	0 52
20.1	0.0									
					6.84		76,440			

CANANDAIGUA LAKE.

0	42.3	100.0	57.2	0-10	10.4	24.4	362.2	22.1	5.1	2 55
5	35.4	83.7	50.5	10-20	3.19	7.8	302.6	18.4	14.7	8 22
10	31.9	75.6	48.2	20-30	2.98	7.0	271.7	16.5	15.6	8 52
20	28.7	67.8	46.5	30-40	2.98	7.1	241.2	14.7	15.2	8 39
30	25.7	60.8	46.3	40-50	4.07	9.6	206.3	12.6	10.7	6 07
40	22.7	53.7	44.9	50-60	6.36	15.0	153.4	9.4	5.0	3 22
50	18.6	44.1	42.4	60-70	7.85	18.6	80.2	4.0	2.1	1 15
60	12.3	29.0	32.7	70-80	4.32	10.2	22.2	1.4	1.0	1 05
70	4.42	10.5	15.1	80-84	.10	.2	.12	.0	.3	0 10
75	1.99	4.7	9.5							
80	.10	.2	1.6							
83.5	0.0									
					42.3		1640.1			

TABLE XV.—HYDROGRAPHIC DETAILS—Continued.

CAYUGA LAKE.

Depth.	Area.		Length of contours.	Depth.	Area.		Volume.		Slope.	
	<i>Sq. km.</i>	<i>Per cent.</i>			<i>Sq. km.</i>	<i>Per cent.</i>	<i>Thousand cu. m.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>° ' "</i>
<i>Meters.</i>			<i>Km.</i>	<i>Meters.</i>						
0	172.1	100.0	153.8	0-10	47.4	27.5	1,435.7	15.4	2.9	1 40
5	138.7	78.0	116.5	10-20	12.7	7.4	1,183.4	12.6	7.6	4 21
10	124.8	72.5	100.9	20-30	8.0	4.6	1,080.2	11.5	11.5	6 34
20	112.0	65.1	93.3	30-40	10.1	5.9	989.6	10.6	8.8	5 02
30	104.0	60.5	90.8	40-50	12.0	7.0	878.7	9.4	7.1	4 04
40	93.9	54.6	86.4	50-60	8.3	4.8	777.3	8.3	9.0	5 39
50	81.9	47.6	83.9	60-70	7.8	4.6	696.4	7.4	10.0	5 43
60	73.6	42.8	80.4	70-80	7.1	4.1	622.0	6.6	10.6	6 03
70	65.8	38.2	76.3	80-90	8.0	4.6	546.8	5.8	8.0	5 05
80	58.7	34.1	72.4	90-100	8.4	4.9	464.8	5.0	7.6	4 21
90	50.7	29.5	68.9	100-110	8.4	4.9	380.5	4.1	6.6	3 47
100	42.3	24.6	58.2	110-120	17.9	10.4	244.2	2.6	2.6	1 30
110	33.9	19.7	53.9	120-130	15.3	8.9	79.1	0.8	1.5	0 52
120	16.0	9.3	39.4	130-133	0.8	0.4	0.7		1.0	0 34
125	7.4	4.3	30.3							
130	0.8	0.4	6.2							
132-6	0.0									
					172.2		9,379.4			

KEUKA LAKE.

0	47.0	100.0	111.2	0-10	7.30	15.6	432.6	30.2	12.4	7 04
10	39.7	84.4	99.5	10-20	5.49	11.7	368.8	25.7	17.7	10 02
20	34.2	72.8	95.8	20-30	7.79	16.6	302.0	21.1	11.7	6 40
30	26.4	56.2	86.4	30-40	11.30	24.0	204.7	14.4	6.1	3 29
40	15.1	32.1	50.4	40-50	7.92	16.0	108.8	7.4	5.3	3 02
50	7.17	15.2	35.8	50-57	7.17	15.2	16.7	1.2	1.4	0 48
55-8	0.0									
					47.0		1,433.7			

OWASCO LAKE.

0	26.7	100.0	41.6	0-10	5.38	20.1	238.3	30.5	7.3	4 11
10	21.3	79.8	37.3	10-20	4.27	16.0	191.3	24.5	8.3	4 44
20	17.0	63.8	33.9	20-30	2.41	9.0	158.1	20.3	13.2	7 36
30	14.6	54.8	20.0	30-40	4.37	16.4	122.8	15.7	6.0	3 26
40	10.2	38.4	22.1	40-50	6.57	24.6	66.9	8.6	2.7	1 33
50	3.68	13.8	13.7	50-54	3.68	13.8	3.31	0.4	2.7	1 33
54-0										
					26.68		780.7			

SENECA LAKE.

0	175.4	100.0	128.3	0-10	22.6	12.0	1,639.7	10.6	5.4	3 05
10	152.8	87.1	115.1	10-20	11.1	6.3	1,472.6	9.5	10.2	5 50
20	141.7	80.7	111.2	20-30	7.6	4.3	1,378.7	8.0	14.0	7 58
30	134.1	76.3	109.6	30-40	8.1	4.6	1,300.4	8.4	13.5	7 41
40	126.0	71.8	108.4	40-50	9.2	5.2	1,214.1	7.8	11.8	6 44
50	116.9	66.6	107.2	50-60	10.0	5.7	1,113.9	7.2	10.5	6 00
60	106.9	60.8	102.6	60-70	6.9	4.0	1,034.1	6.6	14.6	8 18
70	100.0	56.0	100.5	70-80	6.3	3.5	968.1	6.2	16.1	9 09
80	93.7	53.3	99.9	80-90	8.1	4.6	896.0	5.8	12.1	6 34
90	85.6	48.8	94.8	90-100	6.0	3.4	826.0	5.3	15.7	8 55
100	79.6	45.3	92.3	100-110	5.7	3.2	767.9	4.0	15.8	8 58
110	73.9	42.1	89.1	110-120	5.7	3.2	713.3	4.6	15.4	8 45
120	68.2	38.0	86.5	120-130	6.4	3.7	649.8	4.2	13.1	7 28
130	61.8	35.2	82.9	130-140	11.7	6.7	558.5	3.6	6.6	3 48
140	50.0	28.5	73.1	140-150	10.2	5.8	448.5	2.0	6.0	3 57
150	39.8	22.2	67.8	150-160	12.6	7.2	333.2	2.1	4.9	2 47
160	27.2	15.5	55.0	160-170	15.7	8.0	188.0	1.2	2.8	1 35
170	11.5	6.5	32.4	170-180	9.3	5.3	62.3	0.4	2.4	1 21
180	2.2	1.2	11.6	180-188	2.2	1.2	4.3	0.03	1.7	1 00
188	0.0									
					175.4		15,539.5			

TABLE XV.—HYDROGRAPHIC DETAILS—Continued.

SKANEATELES LAKE.

Depth.		Area.		Length of contours.	Depth.		Area.		Volume.		Slope.	
<i>Meters.</i>	<i>Sq. km.</i>	<i>Per cent.</i>	<i>Km.</i>		<i>Meters.</i>	<i>Sq. km.</i>	<i>Per cent.</i>		<i>Thousand cu. m.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>° ' "</i>
0	35.9	100.0	52.0	0-10	8.82	24.5	314.0	20.1	5.51	3	09	
10	27.1	75.5	45.2	10-20	2.93	8.2	256.3	16.4	15.1	8	35	
20	24.2	67.3	43.8	20-30	2.42	6.7	229.4	14.7	17.7	10	02	
30	21.7	60.5	42.0	30-40	2.14	6.0	206.5	13.2	19.2	10	52	
40	19.6	54.6	40.3	40-50	2.84	7.9	181.6	11.6	13.9	7	55	
50	16.8	46.7	38.9	50-60	2.80	7.8	153.8	9.8	13.9	7	55	
60	14.0	38.9	36.1	60-70	3.65	10.2	121.1	7.7	9.1	5	12	
70	10.3	28.7	30.3	70-80	5.05	14.1	76.4	4.9	6.1	3	29	
80	5.26	14.6	31.0	80-85	2.95	8.2	18.4	1.2	3.9	2	14	
85	2.31	6.4	14.6	85-90.5	2.57	6.4	5.3	0.3	1.7	0	58	
90	0.03	.008	0.8									
							36.1		1,562.8			

TABLE XVI.—AREA AND VOLUME OF THE LAKES IN MILES, ACRES, AND FEET.

CANADICE LAKE.

Depth.		Area.		Depth.	Area.		Volume.	
<i>Feet.</i>	<i>Sq. mi.</i>	<i>Acres.</i>	<i>Per cent.</i>	<i>Feet.</i>	<i>Acres.</i>	<i>Per cent.</i>	<i>Million cu. ft.</i>	<i>Per cent.</i>
0	1.00	642	100.0	0-25	130	20.3	677	45.1
25	.80	512	79.8	25-50	108	16.8	492	32.7
50	.63	404	62.9	50-75	187	29.1	322	20.4
75	.34	217	33.8	75-83	217	33.8	14	.9
83								
					642		1,505	

CANANDAIGUA LAKE.

0	16.3	10,440	100.0	0-50	2,890	27.7	19,390	33.3
50	11.8	7,550	72.3	50-100	1,250	12.0	14,460	24.0
100	9.84	6,300	60.2	100-150	1,260	12.0	12,240	21.0
150	7.87	5,040	48.3	150-200	2,200	21.1	8,925	15.3
200	4.44	2,840	27.4	200-250	990	9.5	3,045	5.2
250	2.90	1,850	17.7	250-274	1,850	17.7	130	.2
274								
					10,440		58,190	

CAYUGA LAKE.

0	66.4	42,520	100.0	0-50	13,440	31.6	77,465	23.2
50	45.4	29,080	68.3	50-100	3,490	8.2	59,460	17.8
100	40.0	25,590	60.2	100-150	4,100	9.6	51,160	15.3
150	33.6	21,490	50.6	150-200	3,500	8.2	42,940	12.0
200	28.1	17,990	42.3	200-250	2,820	6.7	36,070	10.0
250	23.7	15,170	35.7	250-300	2,910	6.8	29,815	8.0
300	19.2	12,260	28.8	300-350	3,170	7.5	23,165	6.0
350	14.2	9,090	21.4	350-400	5,980	14.1	11,065	3.3
400	4.90	3,110	7.3	400-435	3,110	7.3	1,628	.4
435								
					42,520		332,788	

TABLE XVI.—AREA AND VOLUME OF THE LAKES IN MILES, ACRES, AND FEET—Continued.

KEUKA LAKE.

Depth.				Area.			Volume.	
Feet.	Sq. mi.	Acres.	Per cent.	Feet.	Acres.	Per cent.	Million cu. ft.	Per cent.
0	18.1	11,610	100.0	0-50	2,520	21.7	22,675	45.2
50	14.2	9,090	78.4	50-100	2,720	23.5	16,775	33.4
100	9.96	6,370	54.0	100-150	3,750	32.3	9,380	18.7
150	4.09	2,620	22.5	150-186	2,620	22.6	1,370	2.7
183								
					11,610		50,200	

OTISCO LAKE.

0	2.64	1,689	100.0	0-25	595	35.2	1,470	54.3
25	1.71	1,094	64.8	25-50	255	15.1	1,050	38.8
50	1.31	839	49.6	50-66	839	49.6	190	7.0
66								
					1,689		2,710	

OWASCO LAKE.

0	10.3	6,600	100.0	0-50	1,960	29.7	12,271	44.0
50	7.26	4,640	70.4	50-100	1,150	17.4	8,965	32.8
100	5.45	3,490	52.0	100-150	1,910	28.0	5,490	20.0
150	2.47	1,580	24.0	150-177	1,580	24.0	626	2.3
177								
					6,600		27,352	

SENECA LAKE.

0	67.7	43,330	100.0	0-50	7,120	16.4	86,165	15.7
50	56.6	36,210	83.6	50-100	3,210	7.4	75,265	13.8
100	51.6	33,000	76.2	100-150	3,160	7.3	66,725	12.2
150	46.6	29,840	68.0	150-200	3,630	8.4	60,980	11.2
200	41.0	26,210	60.5	200-250	3,550	8.2	54,210	9.0
250	37.0	23,660	54.6	250-300	2,760	6.4	48,305	8.0
300	32.7	20,900	48.2	300-350	2,180	5.0	43,110	7.0
350	29.3	18,720	43.2	350-400	2,220	5.1	38,330	7.0
400	25.8	16,500	38.1	400-450	2,410	5.6	32,155	5.0
450	20.5	13,090	30.2	450-500	3,950	9.1	24,100	4.4
500	14.3	9,140	21.1	500-550	5,340	12.3	13,050	2.4
550	5.64	3,800	7.7	550-600	2,290	5.3	3,410	0.6
600	2.35	1,510	0.3	600-618	1,510	3.5	40	
618								
					43,330		545,845	

SKANEATELES LAKE.

0	13.9	8,900	100.0	0-50	2,550	28.6	16,495	20.8
50	9.92	6,350	71.5	50-100	1,010	11.4	12,695	23.0
100	8.34	5,340	60.2	100-150	890	10.0	10,800	10.5
150	6.95	4,450	50.1	150-200	1,090	12.3	8,465	15.0
200	5.25	3,360	37.9	200-250	1,580	17.7	5,480	9.0
250	2.78	1,780		250-297	1,780	20.0	1,220	2.2
297								
					8,900		55,155	

TEMPERATURE OBSERVATIONS.

The temperatures observed in 1910 are stated, with the gases, in table XVIII, and are shown in figures 8-17. The bottom temperatures, stated in table III, are derived from these observations, the temperature curve being extended, if necessary, to the deepest water.

TABLE XVII.—TEMPERATURE OBSERVATIONS.

WINTER TEMPERATURES, 1911, 1912.

Depth, meters.	Cayuga, Feb. 13, 1911; foggy, calm.	Owasco.		Seneca, Feb. 10, 1911; clear, light south.	Skaneateles.	
		Feb. 11, 1911; snow, ice; 11 cm.	Mar. 1, 1912; clear, ice; 52 cm.		Feb. 11, 1911; clear, ice; 6-8 cm.	Mar. 7, 1912; clear, ice; 50 cm.
0	2.00	0.10	0.80	3.25	0.70	1.00
5	.....	.70	1.30	.....	.....	2.20
10	2.10	.70	1.30	3.30	.70	2.25
20	.....	.....	1.40	3.40	1.00	2.40
30	2.30	.75	1.60	.....	1.20	2.40
40	.....	.80	2.00	.....	.....	2.50
50	.....	^a 1.00	^b 2.25	.....	^c 1.20	2.60
60	2.50	.....	.....	.....	.....	2.70
70	.....	.....	.....	.....	.....	3.00
80	.....	.....	.....	3.40	.....	^d 3.10
90	.....	.....	.....	.....	.....	.....
100	.....	.....	.....	.....	.....	.....
105	2.75	.....	.....	.....	.....	.....
160	.....	.....	.....	3.50	.....	.....
Mud...	.....	1.2	^e 2.60	.....	.....	.....

SUMMER TEMPERATURES, 1911, 1912.

Depth, meters.	Canandaigua, Sept. 4, 1911; clear, calm; mean of 4 series.	Cayuga, Sept. 2, 1911; clear, fresh S. wind.	Kenka, Sept. 5, 1911; part cloudy; light S. wind.	Owasco, Sept. 3, 1911; clear, light N. wind.	Owasco, Sept. 13, 1912; clear, calm.	Seneca, Sept. 1, 1911; hazy, light S. or calm.	Skaneateles, Sept. 3, 1911; clear, fresh NW. wind.	Skaneateles, Oct. 18 1912; clear, calm.
0	20.7	20.0	20.6	19.8	19.6	20.0	19.6	14.0
5	19.8	.....	20.4	19.7	19.3	19.4	19.6	13.8
10	19.5	19.8	20.0	19.5	19.2	19.0	19.5	13.7
11	.....	.....	19.5	.....	19.0	.....	.....	.....
12	18.3	.....	14.9	19.3	18.8	18.8	.....	.....
13	.....	.....	12.1	19.1	18.4	.....	.....	.....
14	.....	19.6	10.3	17.3	18.3	.....	.....	.....
15	15.7	19.0	9.4	16.6	18.2	18.4	19.3	13.6
16	12.2	18.5	.....	15.9	17.0	17.3	18.8	.....
17	11.5	16.1	7.3	15.4	15.8	14.9	17.5	.....
18	10.6	13.8	.....	13.0	.....	12.3	16.4	.....
19	.....	.....	.....	12.5	.....	11.1	14.7	.....
20	7.7	10.1	6.7	9.1	11.9	10.2	13.3	13.5
25	5.6	7.9	5.8	7.6	9.1	6.8	7.7	13.5
30	5.2	5.9	5.6	6.6	8.3	5.8	6.5	10.3
40	4.6	4.8	5.0	5.5	7.6	4.8	5.7	6.8
50	4.6	4.5	^e 4.8	^e 5.3	^e 7.3	4.3	5.5	6.5
60	4.4	4.5	.....	.....	.....	.....	.....	6.4
70	4.3	4.4	.....	.....	.....	4.2	^f 4.7	6.3
80	^g 4.3	4.2	.....	.....	.....	4.2	.....	^h 6.3
100	.....	4.1	.....	.....	.....	4.1	.....	.....
120	.....	ⁱ 4.1	.....	.....	.....	4.1-	.....	.....
164	.....	.....	.....	.....	.....	4.0+	.....	.....

^a 51 meters.^b 48 meters.^c Off Mandana. Lake only part frozen. Deeper water not covered by ice. Depth, 51 meters.^d 75 meters.^e 49 meters.^f 69 meters.^g 73 meters.^h 80 meters.ⁱ 121 meters.

DISSOLVED GASES.

The depth is given in meters, the temperature in degrees centigrade, and the gases in cubic centimeters per liter of water. The last column shows the per cent of saturation of the oxygen. In the free carbon dioxide, a minus sign indicates that the water was alkaline, a plus sign that it was acid, and neut. that it was neutral to phenolphthalein. The degree of alkalinity or acidity is indicated by the number of cubic centimeters of carbon dioxide that would have to be added or removed to make the water neutral.

TABLE XVIII.—OBSERVATION ON GASES.

Depth, meters.	Temper- ature.	Carbon dioxide.		Oxygen.	
		Free.	Fixed.	Cc. per liter.	Per cent of sat.
CANADICE LAKE, AUG. 16, 1910.					
0	22.2	-0.51	6.83	6.50	102.7
5	22.1	.....	.....	6.60	104.1
8	20.6	-0.51	6.83	6.88	105.7
9	19.7	-0.25	6.83	6.98	105.6
10	15.2	+0.25	6.83	7.73	107.4
11	13.0	+0.89	.....	6.89	90.1
12	11.2	+1.51	.....	6.13	78.5
15	9.3	+2.53	6.83	5.29	64.8
18	8.5	+3.29	.....	4.17	50.2
20	8.2	+4.05	6.83	3.37	40.3
22	.....	.....	.....	2.42	28.8
24	8.0	+4.45	6.83	2.39	28.4
CANANDAIGUA LAKE, AUG. 20, 1910.					
0	21.7	-3.00	24.03	6.75	105.7
5	21.3	.....	.....	6.75	105.0
10	20.6	-3.00	24.03	7.02	107.9
15	13.1	-1.54	24.54	7.83	104.3
20	8.2	Neut.	.....	7.90	94.4
25	7.6	.....	.....	7.90	93.1
30	6.3	+0.5	24.8	8.10	92.6
40	.....	.....	.....	8.20	93.0
60	.....	+0.75	24.8	8.00	89.9
70	.....	+0.9	25.30	7.13	80.0
80	5.4	+1.26	25.60	6.45	72.1
CAYUGA LAKE, AUG. 11, 1910.					
0	19.8	-2.50	22.20	6.65	100.4
5	19.6	.....	.....	6.85	103.5
10	19.6	-2.50	22.20	6.84	103.3
15	19.2	-2.50	22.20	7.00	105.0
18	15.9	-0.40	22.20	8.28	116.7
20	11.5	-0.40	22.20	8.27	106.5
25	8.6	Neut.	22.80	8.53	102.9
30	7.0	Neut.	.....	8.68	100.9
40	5.9	+0.12	22.80	8.80	99.6
50	5.1	.....	.....	8.93	99.1
75	4.5	+0.40	.....	9.05	98.9
100	4.5	+0.75	23.30	7.92	86.6
122	4.4	+1.00	23.8	7.63	83.2
CONESUS LAKE, AUG. 25, 1910.					
0	21.8	-2.50	23.02	6.16	96.6
5	21.6	.....	.....	6.12	95.7
8	21.4	-2.50	23.02	6.00	93.5
9	20.3	+1.77	24.03	1.50	22.9
10	16.4	+3.03	25.30	0.11	1.5
11	15.5	.....	.....	0.05	0.7
12	14.6	+3.54	25.80	0.06	0.8
15	13.2	.....	26.30	Tr.	.....
17.5	12.5	+4.04	28.10	0.00	0.0
HEMLOCK LAKE, AUG. 23, 1910.					
0	21.7	-1.80	12.90	6.77	106.0
5	21.5	-1.80	12.90	6.93	108.2
8	21.4	.....	.....	6.92	107.8
9	19.8	-1.30	12.90	7.02	106.5
10	18.0	.....	12.90	7.42	108.9
12	15.2	+0.38	12.90	7.73	107.4
15	10.9	.....	.....	5.36	68.2
18	9.8	+3.29	.....	3.80	47.1
24	9.5	+5.06	.....	1.37	16.8
27	9.3	+7.10	12.90	0.70	8.5
KEUKA LAKE, AUG. 18, 1910.					
0	21.3	-2.00	16.75	6.91	107.5
5	21.3	-1.80	16.75	7.05	109.6
10	15.5	-0.35	16.75	8.01	112.0
15	9.7	+0.25	16.75	8.10	100.2
20	8.3	+0.63	.....	7.80	93.4
30	7.4	+1.01	16.75	7.47	87.6
40	.....	.....	.....	7.51	87.1
51	6.4	+2.53	16.75	5.57	63.8
OTISCO LAKE, AUG. 16, 1910.					
0	23.0	-2.50	21.00	6.72	107.7
5	22.4	-3.00	21.00	6.81	107.9
8	20.7	-2.30	21.00	6.70	103.1
9	.....	-2.20	21.75	5.77	85.6
10	17.4	+1.01	23.50	3.00	43.5
11	.....	+2.30	25.30	1.19	10.6
12	13.5	+2.80	25.80	0.34	4.5
15	12.6	+3.03	28.10	0.05	0.65
17	12.3	+3.80	28.30	0.00	0.0
OWASCO LAKE, AUG. 13, 1910.					
0	21.5	-2.50	22.20	6.82	106.4
5	20.3	.....	.....	7.03	107.5
10	20.2	.....	.....	6.91	105.5
12.5	19.1	.....	.....	6.80	101.8
15	15.1	-2.50	22.20	7.97	110.6
17.5	11.2	+0.50	.....	7.56	96.8
20	9.8	+0.63	22.20	7.59	94.1
30	7.9	+0.90	22.20	7.57	89.9
40	7.5	+1.26	22.20	7.28	85.6
50	7.1	+1.26	22.50	6.82	79.5

TABLE XVIII.—OBSERVATIONS ON GASES—Continued.

Depth, meters.	Temper- ature.	Carbon dioxide.		Oxygen.		Depth, meters.	Temper- ature.	Carbon dioxide.		Oxygen.	
		Free.	Fixed.	Cc. per liter.	Per cent of sat.			Free.	Fixed.	Cc. per liter.	Per cent of sat.
SENECA LAKE, AUG. 3, 1910.						SKANEATELES LAKE, AUG. 15, 1910.					
0	20.2	—2.50	22.00	6.85	104.6	0	22.7	—1.25	21.25	6.75	107.6
5	19.6	.....	.....	7.00	105.7	5	19.8	.....	.....	7.02	106.4
10	19.0	—2.50	22.00	7.40	110.6	10	17.8	.....	.....	7.51	109.8
15	17.2	.....	.....	7.80	112.8	15	12.6	—1.25	21.25	9.15	120.6
20	11.6	—1.00	22.00	8.40	108.4	20	8.6	—0.55	21.25	9.20	111.0
30	8.3	—0.50	22.00	8.80	105.4	25	.....	Neut.	.....	8.88	104.9
50	5.2	.....	.....	8.70	99.0	30	6.8	+0.25	21.25	8.77	101.4
75	4.6	.....	.....	8.90	97.5	50	5.9	+0.75	21.40	8.65	97.9
100	.....	Neut.	22.00	9.00	98.4	70	.....	.....	.....	8.24	92.8
130	.....	+0.25	22.20	9.10	99.2	83	5.5	+1.00	21.80	7.89	88.4
150	.....	+0.40	22.20	8.55	93.0						
173	4.2	+1.26	22.20	8.45	91.7						

DISTRIBUTION OF PLANKTON.

Table XIX shows the vertical distribution of the various plankton organisms, giving the number of individuals per cubic meter of water at the different depths. The members grouped in the different columns are indicated as follows: 1. Cladocera, B=*Bosmina*, C=*Ceriodaphnia*, D=*Daphnia*, Di=*Diaphanosoma*, L=*Leptodora*, P=*Polyphemus*; 2. Copepoda, C=*Cyclops*, D=*Diaptomus*, E=*Epischura*, L=*Limnocalanus*; 3. Nauplii; 4. Rotifera, An=*Anuræa*, As=*Asplanchna*, C=*Conochilus*, N=*Notholca*, Pl=*Ploesoma*, P=*Polyarthra*, T=*Triarthra*; 5. Protozoa, C=*Ceratium*, D=*Dinobryon*, M=*Mallomonas*, V=*Vorticella*; 6. Green and blue-green algæ, An=*Anabaena*, Ap=*Aphanocapsa*, Aph=*Aphanizomenon*, C=*Clathrocystis*, Coe=*Cælosphærium*, G=*Gloeocapsa*, L=*Lyngbya*, O=*Oscillatoria*, S=*Staurastrum*; 7. Diatoms, A=*Asterionella*, C=*Cyclotella*, F=*Fragilaria*, M=*Melosira*, N=*Navicula*, S=*Synedra*, T=*Tabellaria*.

When present in relatively small numbers, some forms showed an irregular distribution—that is, they were not noted at certain depths, but were found both above and below these depths. This does not mean, however, that they were entirely absent at the intermediate levels, but that they were not found in that portion of the catch which was counted.

TABLE XIX.—ANALYSIS OF PLANKTON CATCHES.

CANADICE LAKE, AUG. 24, 1910.

Depth, meters.	Cladocera.		Copepoda.		Nauplii.	Rotifera.	Protozoa.	Green and blue-green algæ.		Diatoms.	
0.....	{		C				C	An		A	
	Di	3,650	D	2,800	700		V	Ap	6,400	F	63,300
		1,400		48,600				C	42,200		42,200
									189,000		
5.....	{		C				C	C	294,000	A	126,600
	Di	5,000	D	4,200	5,700		V	G	63,300	T	21,100
		2,100		20,700							
8.....	{		C			P	C	An		A	
	Di	2,100	D	2,100	10,700	1,400	V	C	700		189,900
		2,800		12,100					168,800		
10.....	{		C			P	C	C		A	
	D	700	D	2,800	40,000	4,200	D	G	42,200		759,600
				12,800			M		42,200		
									2,110,000		

TABLE XIX.—ANALYSIS OF PLANKTON CATCHES—Continued.

CANADICE LAKE, AUG. 24, 1910—Continued.

Depth, meters.	Cladocera.	Copepoda.	Nauplii.	Rotifera.	Protozoa.	Green and blue-green algae.	Diatoms.
12.....	{ D 700	C 5,000 D 12,800	20,700	An 1,400 N 200	C 21,100 M 126,600	C 2,100 G 2,100	A 1,561,400
15.....	{ D 700	D 4,200	35,700	N 700	M 42,200	C 1,400 G 700	A 400,900
18.....	{ D 200	D 4,200	49,200		C 21,100	C 200 G 200	A 232,100
20.....		{ D 2,800	97,100		C 7,000		A 105,500 T 21,100
23-5.....		{ C 6,400 D 9,200	15,700		C 147,700 M 21,100		A 163,300

CANANDAIGUA LAKE, AUG. 20, 1910.

0-5.....	{ B 260 D 920 Di 3,270	C 4,500 D 14,200	18,500	C 130 P 1,300	C 23,200	Ap 11,600 C 61,900 S 3,800	A 34,800 F 3,800
5-10.....	{ B 260 D 1,600 Di 2,500	C 3,700 D 7,200	5,900	C 130 P 2,100	C 92,900	Ap 11,600 C 58,000 Coe 3,800	A 34,800 F 200
10-15.....	{ B 260 D 1,300 Di 2,750	C 2,400 D 7,600	2,150	C 520 N 130 P 650	C 50,300 D 7,700	Ap 3,800 C 54,200 Coe 23,600	A 50,300 T 3,800
15-20.....	{ B 130 D 130 Di 260	D 4,190	390	C 520 P 200	C 3,800	An 7,700 Ap 7,700 C 15,500 Coe 42,600	A 2,100 T 1,200
20-30.....	{ B 100 D 2,230 L 30	D 1,640 L 460		N 130	C 3,800	An 1,900 Ap 7,700 C 7,700 Coe 7,700	
30-40.....	{ B 200 D 590	D 400 L 130	65	C 65 N 130	C 1,900	Ap 1,900 C 1,900 Coe 3,800	F 1,900
40-60.....	{ B 230 D 25	D 360 L 100	25	C 130		Ap 2,900 C 2,900 Coe 1,900	A 960 F 960 T 960
60-70.....	{ B 130	D 400 L 130		C 65 P 30	C 1,900	C 1,900 Coe 3,800	
70-80.....	{ B 200	D 850 L 200			C 1,900	Ap 1,900 Coe 3,800	

CAYUGA LAKE, AUG. 12, 1910.

0.....	{ B 12,800 C 1,400	C 3,500 D 1,400	4,300	An 350 As 21,400 P 100,700	C 2,525,000 D 15,500 V 2,800	An 2,800	A 4,494,000 F 2,011,000 T 299,600
5.....	{ B 32,100 P 700	C 2,800 D 1,400	1,400	An 150 As 20,000 Pl 2,800 P 106,400	C 1,455,200 D 15,500 V 2,100	An 2,100 C 42,800	A 3,809,000 F 1,326,800 T 128,400
10.....	{ B 65,700 C 700	D 1,400	6,400	An 5,700 As 20,000 Pl 3,600 P 95,700	C 1,412,000 D 15,500	C 42,800	A 4,280,000 F 2,268,000 T 214,000

TABLE XIX.—ANALYSIS OF PLANKTON CATCHES—Continued,

CAYUGA LAKE, AUG. 12, 1910—Continued.

Depth, meters.	Cladocera.	Copepoda.	Nauplii.	Rotifera.	Protozoa.	Green and blue-green algae.	Diatoms.
15.....	{ B 55,700	C D 700 1,400	8,500	An 2,100 As 24,200 Pl 5,700 P 40,700	C D 1,241,000 128,400	C 13,000	A 4,365,000 F 1,797,600 T 85,600
20.....	{ B 17,100	C D 5,700 1,400	70,700	An 54,400 As 12,100 P 21,400	C D 428,000 42,800 M 770,400	C 8,500	A 1,583,600 F 1,112,800 T 642,000
30.....	{ B 5,000	C D 4,200 1,400	12,100	An 6,400 N 700 P 40,000	C M 299,600 95,600	C 95,600	A 1,027,000 F 470,800 T 470,800
30-50.....	{ B 360	C D 720 790	1,200	An 200 N 100 P 2,100	C M 7,600 1,900	C 3,500	A 67,500 F 23,100 T 27,000
50-75.....	{ B 80	C D 640 340	1,000	An 50 N 50 P 630	C 10,800	C 1,500	A 41,800 F 7,700 T 7,700
75-100.....	{ B 670	C D 80 20	60	An 30 N 30 P 630	C 26,300	C 1,500	A 35,600 F 20,000 T 7,700
100-120.....	{ B 60	C D 50 100	160	An 90 N 30 P 180	C M 15,000 1,900	C 1,500	A 30,900 F 9,600 T 15,200

CONESUS LAKE, AUG. 25, 1910.

0.....	{ D 10,700	C 5,000	8,000	P 20,700	C D M V 464,200 42,200 24,400 1,400	An Aph C Coe G 1,400 42,200 84,400 126,600 42,200	A F 42,200 1,139,400
5.....	{ D 7,100	C 8,000	15,700	N P 700 25,700	C M 211,000 42,200	An Coe L S 84,400 295,400 42,200 42,200	A F 42,200 1,434,800
8.....	{ D 4,200	C D 2,800 2,800	9,200	N P 700 22,100	C M V 253,200 84,400 2,100	An Coe S 2,100 717,400 84,400	A F 42,200 1,899,000
9.....	{ D 5,700	C D 6,400 43,500	38,400	An P 700 4,200	C M 422,000 84,400	Coe S 379,800 42,200	A F 84,400 1,477,000
10.....	{ D 50	C D 62,100 700	122,800	An N P 700 700 1,400	C 337,600	Coe S 126,600 42,200	F 295,400
12.....	{ D 30	C 6,400	7,100	N P 10 30	C 84,400	Coe 21,100	F 21,100
15.....		{ C 400		N P 30 30	C 21,100	Coe 21,100	F 42,200
17.5.....					{ C 42,200	Coe S 126,600 2,100	F 2,100

TABLE XIX.—ANALYSIS OF PLANKTON CATCHES—Continued.

HEMLOCK LAKE, AUG. 23, 1910.

Depth, meters.	Cladocera.	Copepoda.	Nauplii.	Rotifera.	Protozoa.	Green and blue-green algæ.	Diatoms.
0.....	{B 50 D 7,800 Di 1,700	C 2,860 D 2,500	19,300	An 300 P 4,300	C 1,055,000	Aph 42,200 C 84,400 Coe 337,600	A 738,500 F 147,700 T 42,200
5.....	{D 5,000 Di 500 L 200	C 5,000 D 2,800	20,000	C 100 P 4,300	C 1,477,000	C 42,200 Coe 464,200	A 1,266,000 F 42,200 T 126,600
8.....	{D 5,700 Di 700	C 1,400 D 1,400	18,000	C 1,400 N 2,800 P 2,800	C 1,566,400	C 42,200 Coe 295,400	A 970,600 F 337,600 T 126,600
12.....	{D 7,100	C 10,700 D 8,000	81,400	C 700 N 4,200 P 700 T 2,100	C 1,645,800	C 42,200 Coe 1,097,200	A 379,800 F 337,600 T 168,800
15.....	{B 1,000 D 2,100	C 2,800 D 2,800	50,700	An 700 N 700	C 844,000	Coe 422,000	A 126,600 F 465,300
20.....	{B 150 D 150	C 3,600 D 10,000	57,100	N 2,100	C 633,000	Coe 590,800	A 126,600 F 84,400
26.....	{D 300	C 700 D 2,800	11,400	T 4,200	C 211,000	Coe 717,400	A 1,000 F 168,800

KEUKA LAKE, AUG. 18, 1910.

0-5.....	{B 650 C 130 D 130 L 150	C 10,800	1,000	An 2,360 C 260 N 1,440 P 18,300	C 77,400 D 7,700	C 7,700 Coe 7,700	A 619,200 C 15,500 F 866,900 T 38,700
5-10.....	{B 260 D 400	C 17,000	1,300	An 1,300 C 130 N 2,230 P 11,700	C 286,400	C 1,200 Coe 1,100	A 1,153,200 F 1,532,500 T 69,600
10-15.....	{B 130 D 2,230	C 2,750 D 260 E 400	900	An 6,000 As 260 C 260 N 400 P 4,300	C 224,400	Aph 7,700 C 7,700 Coe 7,700 O 77,400	A 921,000 F 1,470,600 T 433,400
15-20.....	{B 260 D 2,490	C 260 D 260 E 520	300	An 2,750 As 400 C 100 N 130 P 3,140 T 130	C 38,700	Aph 5,000 C 7,000 Coe 5,500 O 835,900	A 201,200 F 835,900 T 681,000
20-25.....	{B 260 D 900	C 130 D 4,060	200	An 1,300 C 130 N 130 P 7,700 T 900	C 31,000	Aph 7,000 C 4,000 O 301,800	A 154,800 F 425,700 T 317,300
25-30.....	{B 130 D 260	C 130 D 7,900	400	An 650 P 9,700 T 650	C 15,500	Aph 15,500 C 3,000 O 154,800	A 38,700 F 263,200 T 92,900
30-40.....	{B 130 D 50	C 60 D 2,750	650	An 130 P 3,200 T 390	C 11,500	Aph 1,500 C 3,000 O 23,200	A 34,800 F 50,300 T 31,000
40-50.....	{B 45 D 10	C 200 D 1,230	450	N 260 P 910 T 2,700	C 11,000	C 5,500 O 13,800	A 107,600 F 85,500 T 27,600

TABLE XIX.—ANALYSIS OF PLANKTON CATCHES—Continued.

OTISCO LAKE, AUG. 16, 1910.

Depth, meters.	Cladocera.	Copepoda.	Nauplii.	Rotifera.	Protozoa.	Green and blue-green algae.	Diatoms.
0-6.....	{D 2,830 Di 1,850 L 65	C 13,860 D 5,350	13,860	An 650 N 220 P 7,530	C 148,800	C 49,600 Coe 43,400	F 24,800 M 6,200
6-9.....	{D 2,000 Di 1,100 L 30	C 10,500 D 6,550	8,100	An 500 N 210 P 10,500	C 235,600	C 272,800 Coe 260,400	C 37,200 F 37,200 M 12,400
9-12.....	{D 420	C 1,500 D 27,300	93,200	An 1,260 P 5,900	C 24,800	C 24,800 Coe 148,800	C 86,800 F 49,600
12-17.....	{D 100	C 260 D 650	6,150	P 520	C 15,400	C 7,700 Coe 27,000	A 7,700 C 7,700 F 23,200 T 3,900

OWASCO LAKE, AUG. 13, 1910.

0-5.....	{B 3,400 D 130 Di 400	C 780 D 1,700	33,500	As 1,830 P 9,560	C 54,200 D 1,269,000	C 46,700 G 7,700	
5-10.....	{B 920 D 400 Di 920	C 3,800 D 4,200	13,800	As 700 C 260 P 11,800	C 31,000 D 1,470,600	An 7,700 Aph 38,700 C 62,000	A 500 F 700 T 500
10-15.....	{B 400 D 1,500 Di 400	C 400 D 6,700	3,400	C 130 P 650	D 65,800	An 3,800 Aph 15,500 C 27,100	A 7,700 T 7,700
15-20.....	{B 50 D 130	D 13,000 E 200	5,200	P 520	C 500 D 46,400	Aph 23,200 C 3,800	T 3,800
20-25.....		D 9,300	3,000	P 130	D 34,800	Aph 7,700 C 11,600	A 7,700 T 7,700
25-30.....	{B 50	D 10,400	1,200	P 130	D 54,200	Aph 27,000 C 15,500 O 3,800	
30-35.....		D 10,600	1,700	P 100	D 50,300	Aph 23,200 C 3,800	
35-40.....		D 6,000	650	P 130	D 23,200	Aph 15,500 C 3,800	
40-45.....		D 6,700 L 400	780		D 27,100	Aph 15,500 C 3,800	
45-50.....	{B 30	D 3,800 L 130	520	P 50	D 30,900	C 3,800	

SENECA LAKE, AUG. 4, 1910.

0.....	{P 800	C 2,500	1,250	An 1,250 As 400 Pl 3,300 P 18,000	C 36,900 V 4,100	C 7,700	A 98,400 T 12,300
5.....	{B 11,250 P 400	C 3,750	8,750	An 7,000 As 2,500 N 800 Pl 5,000 P 31,600	C 24,600	A 24,600 C 10,000	A 86,000 T 12,300
10.....	{B 18,000	C 1,600	11,250	An 3,750 As 1,250 P 20,800	C 98,400	C 17,300	A 233,700 F 24,600 T 12,300

TABLE XIX.—ANALYSIS OF PLANKTON CATCHES—Continued.

SENECA LAKE, AUG. 4, 1910—Continued.

Depth, meters.	Cladocera.	Copepoda.	Nauplii.	Rotifera.	Protozoa.	Green and blue-green algae.	Diatoms.
15.....	{ B 24, 100	C D 15, 800 5, 000	44, 100	An 1, 250 As 400 C 1, 600 N 1, 250 P 22, 100	C 24, 600	C 16, 000	A 1, 350, 400 F 12, 300 T 12, 300
20.....	{ B 7, 100	C D 20, 000 8, 000	68, 300	An 1, 250 N 1, 250 P 3, 750	C 12, 300	C 12, 300	A 332, 000 F 36, 900 T 12, 300
50.....	{ B 1, 650	C D 20, 000 20, 000	25, 400	An 200 P 3, 000	C 12, 300	C 500	A 61, 500 F 1, 000 T 500
50-75.....	{ B 25	C D 50 820	2, 000	An 70 P 70	C 500	C 500	A 1, 000 F 250 T 250
75-100.....		{ C D 50 L 250 30	750	An 30 P 130	C 250	C 700	A 250
100-130.....		{ C D 40 L 100 20	280	An 20 P 20	C 600	C 400	A 200
130-165.....		{ C D 20 L 150	400	An 20 P 40	C 170	C 850	A 100 F 500

SKANEATELES LAKE, AUG. 15, 1910.

0-10.....	{ B 1, 000	C D 460 4, 400	13, 700	As 400 C 60 P 460	C D 250, 900 7, 700	An 50, 200 C 19, 300 G 15, 400	A 220, 000 F 3, 800 N 7, 700 S 108, 000
10-20.....	{ B 190 D 400 D 190	C D 260 14, 700	1, 100	P 1, 700	C 243, 200	An 54, 200 Ap 30, 900 C 3, 800 Coe 3, 800	A 4, 092, 000 S 11, 600
20-30.....	{ D 60	C D 60 L 2, 600 60	100	P 2, 360	C 30, 900	An 7, 700 C 1, 100 Coe 900	A 2, 146, 000 S 54, 000
30-50.....	{ B 10 D 30	D 430 L 30	60	P 1, 860	C 9, 600	C 400 Coe 400	A 1, 162, 000 F 1, 900 S 21, 200
50-70.....	{ B 10	D 120 L 60	30	P 1, 000	C 3, 800	Coe 300	A 331, 000 S 5, 800
70-80.....		{ D 60 L 100	10	P 60	C 3, 860	C 150 Coe 100	A 127, 400 S 15, 400

TRANSPARENCY.

The transparency of the water was determined in 1910 by means of a Secchi's disk about 10 centimeters in diameter. The depth at which this disk disappeared from view was as follows:

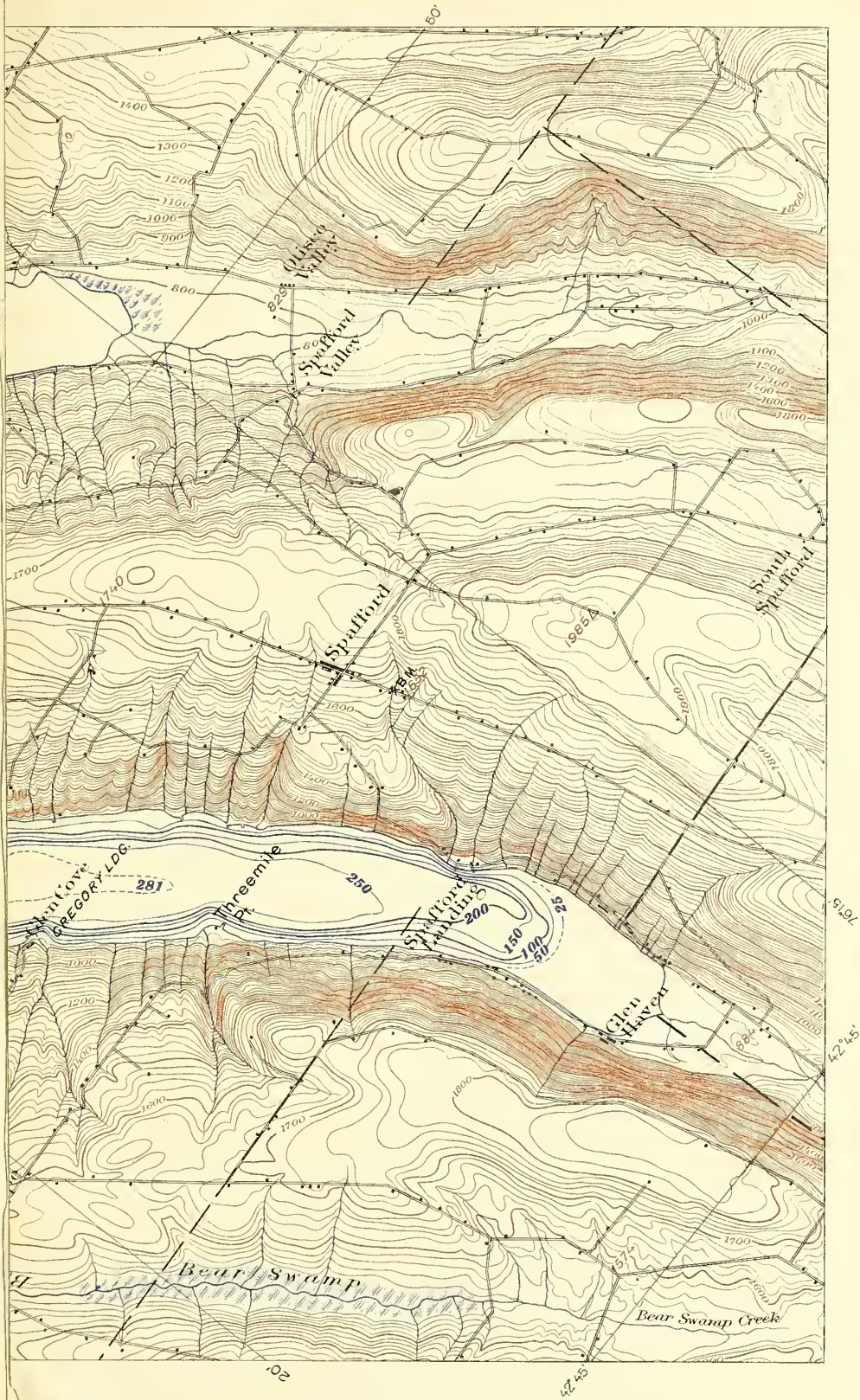
TABLE XX.—TRANSPARENCY OF WATER.

Lakes.	Trans- parency.	Lakes.	Trans- parency.
	<i>Meters.</i>		<i>Meters.</i>
Canadice.....	4.0	Hemlock.....	4.7
Canandaigua.....	3.7	Otisco.....	3.0
Cayuga.....	5.1	Seneca.....	8.3
Conesus.....	6.3	Skaneateles.....	10.3

OXYGEN ABSORPTION.

TABLE XXI.—NUMBER OF CUBIC CENTIMETERS OF OXYGEN ABSORBED BY 1 LITER OF DISTILLED WATER AT DIFFREENT TEMPERATURES FROM A FREE DRY ATMOSPHERE OF 760 MM. PRESSURE.

Temp.	0	1	2	3	4	5	6	7	8	9
—2	10.880	10.850	10.820	10.790	10.760	10.730	10.700	10.670	10.640	10.610
—1	10.580	10.551	10.522	10.493	10.464	10.435	10.406	10.377	10.348	10.319
0	10.290	10.263	10.236	10.209	10.182	10.155	10.128	10.101	10.074	10.047
1	10.020	9.993	9.966	9.939	9.912	9.885	9.858	9.831	9.804	9.777
2	9.750	9.725	9.700	9.675	9.650	9.625	9.600	9.575	9.550	9.525
3	9.500	9.476	9.452	9.428	9.404	9.380	9.356	9.332	9.308	9.284
4	9.260	9.237	9.214	9.191	9.168	9.145	9.122	9.099	9.076	9.053
5	9.030	9.008	8.986	8.964	8.942	8.920	8.898	8.876	8.854	8.832
6	8.810	8.789	8.768	8.747	8.726	8.705	8.684	8.663	8.642	8.621
7	8.600	8.580	8.560	8.540	8.520	8.500	8.480	8.460	8.440	8.420
8	8.400	8.381	8.362	8.343	8.324	8.305	8.286	8.267	8.248	8.229
9	8.210	8.191	8.172	8.153	8.134	8.115	8.096	8.077	8.058	8.039
10	8.020	8.002	7.984	7.966	7.948	7.930	7.912	7.894	7.876	7.859
11	7.840	7.824	7.808	7.792	7.776	7.760	7.744	7.728	7.712	7.696
12	7.680	7.664	7.648	7.632	7.616	7.600	7.584	7.568	7.552	7.536
13	7.520	7.505	7.490	7.475	7.460	7.445	7.430	7.415	7.400	7.385
14	7.370	7.355	7.340	7.325	7.310	7.295	7.280	7.265	7.250	7.235
15	7.220	7.206	7.192	7.178	7.164	7.150	7.136	7.122	7.108	7.094
16	7.080	7.066	7.052	7.038	7.024	7.010	6.996	6.982	6.968	6.954
17	6.940	6.927	6.914	6.901	6.888	6.875	6.862	6.849	6.836	6.823
18	6.810	6.798	6.786	6.774	6.762	6.750	6.738	6.726	6.714	6.702
19	6.690	6.678	6.666	6.654	6.642	6.630	6.618	6.606	6.594	6.582
20	6.570	6.559	6.548	6.537	6.526	6.515	6.504	6.493	6.482	6.471
21	6.460	6.449	6.438	6.427	6.416	6.405	6.394	6.383	6.372	6.361
22	6.350	6.339	6.328	6.317	6.306	6.295	6.284	6.273	6.262	6.251
23	6.240	6.230	6.220	6.210	6.200	6.190	6.180	6.170	6.160	6.150
24	6.140	6.130	6.120	6.110	6.100	6.090	6.080	6.070	6.060	6.050
25	6.040	6.030	6.020	6.010	6.000	5.990	5.980	5.970	5.960	5.950
26	5.940	5.930	5.920	5.910	5.900	5.890	5.880	5.870	5.860	5.850
27	5.840	5.831	5.822	5.813	5.804	5.795	5.786	5.777	5.768	5.759
28	5.750	5.741	5.732	5.723	5.714	5.705	5.696	5.687	5.678	5.669
29	5.660	5.651	5.642	5.633	5.624	5.615	5.606	5.597	5.588	5.579
30	5.570	5.561	5.552	5.543	5.534	5.525	5.516	5.507	5.498	5.489



OTISCO AND SKANEATELES LAKES

(UPPER, SMALLER LAKE IS OTISCO)

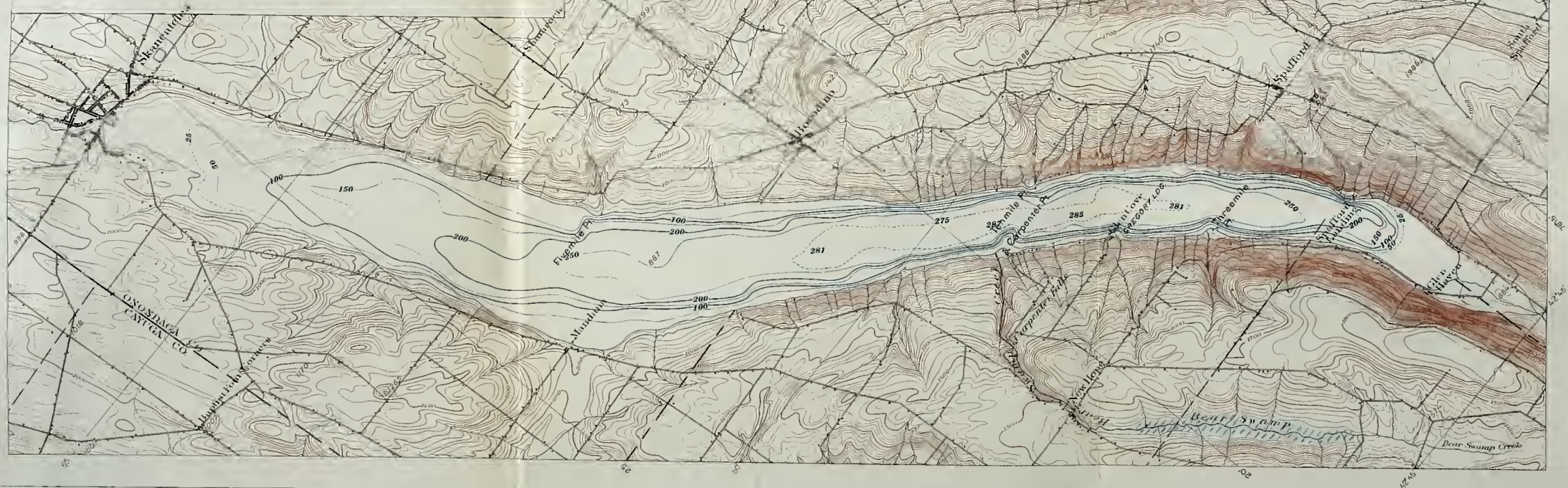
Topography from maps of the United States Geological Survey, 1902

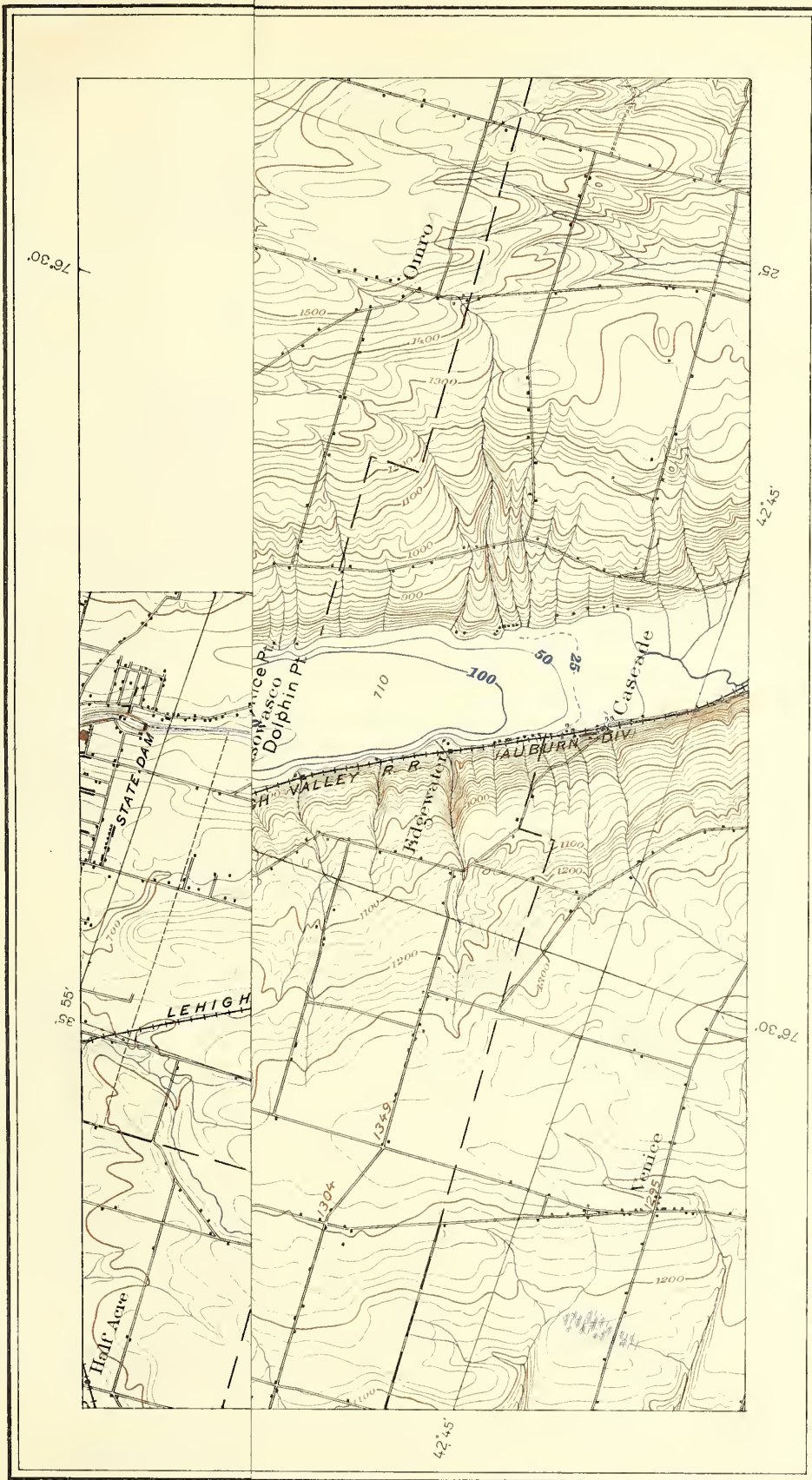
Hydrography from survey by Cornell University
(Skaneateles, 1893; Otisco, 1897)

Contour interval { Topography, 20 feet
Hydrography, 50 feet

Scale 62500

0 1 2 Miles





OWASCO LAKE

Topography from maps of the United States Geological Survey, 1909

Hydrography from survey by Cornell University, 1896-1897

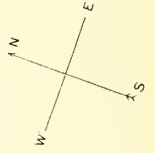
Contour interval { Topography, 20 feet
Hydrography, 50 feet

Scale 1:2500

1 2 3 Miles









CAYUGA LAKE

Topography from maps of the United States Geological Survey, 1902 and 1909
Hydrography from survey by Cornell University, 1874-1878

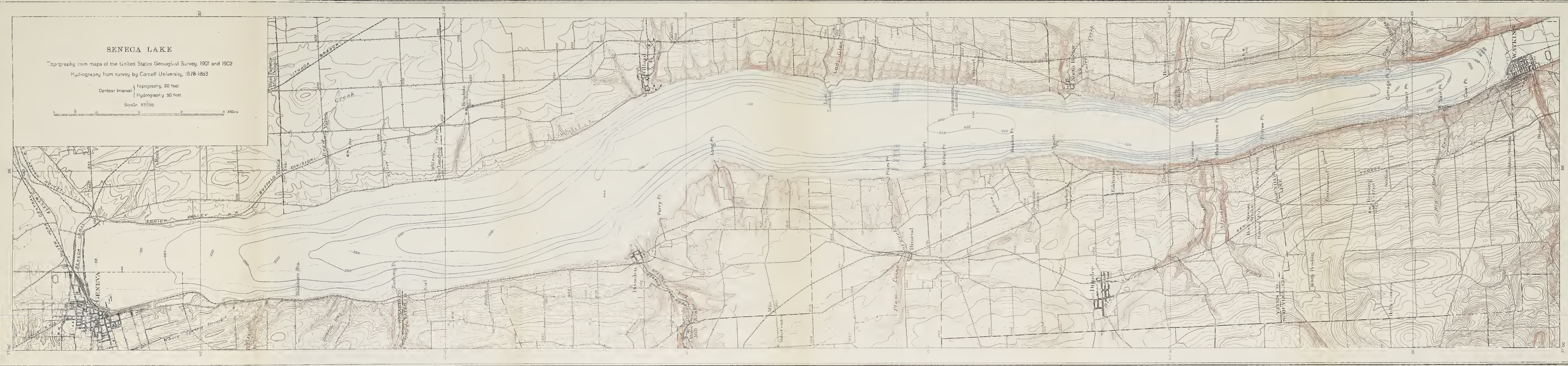
Contour interval Topography, 20 feet
Hydrography, 50 feet

Scale 60000

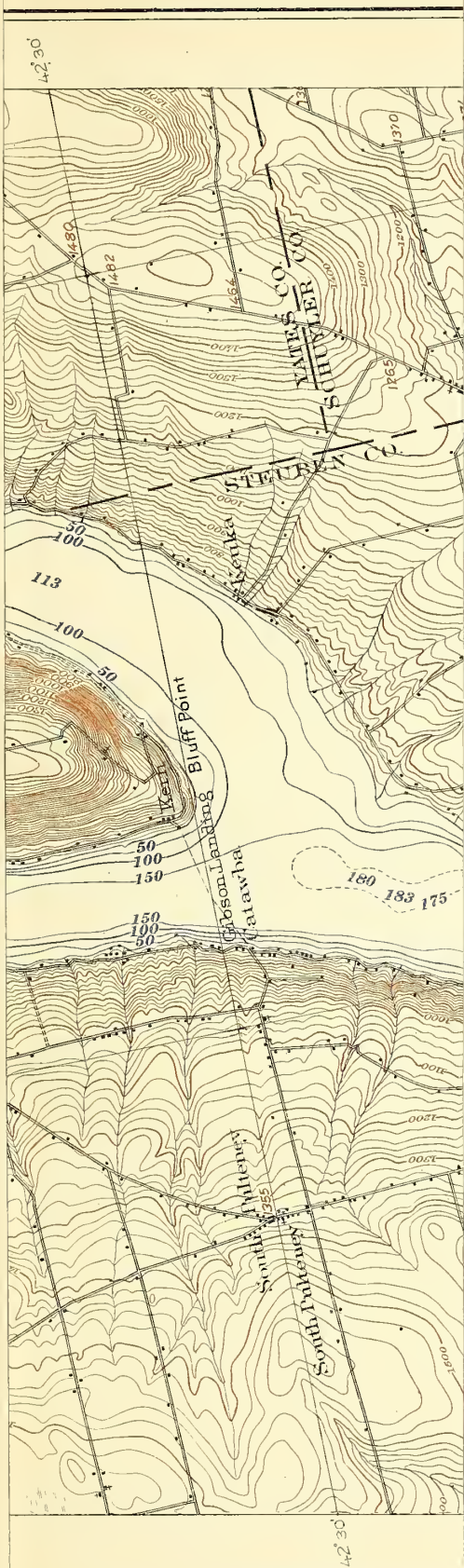
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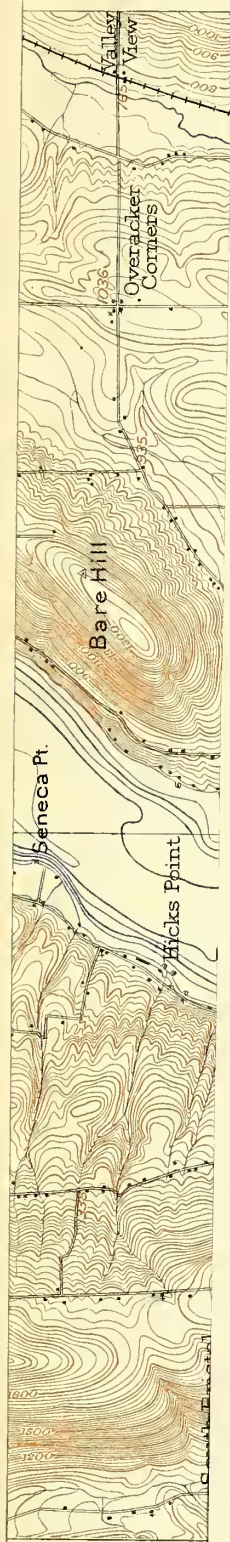












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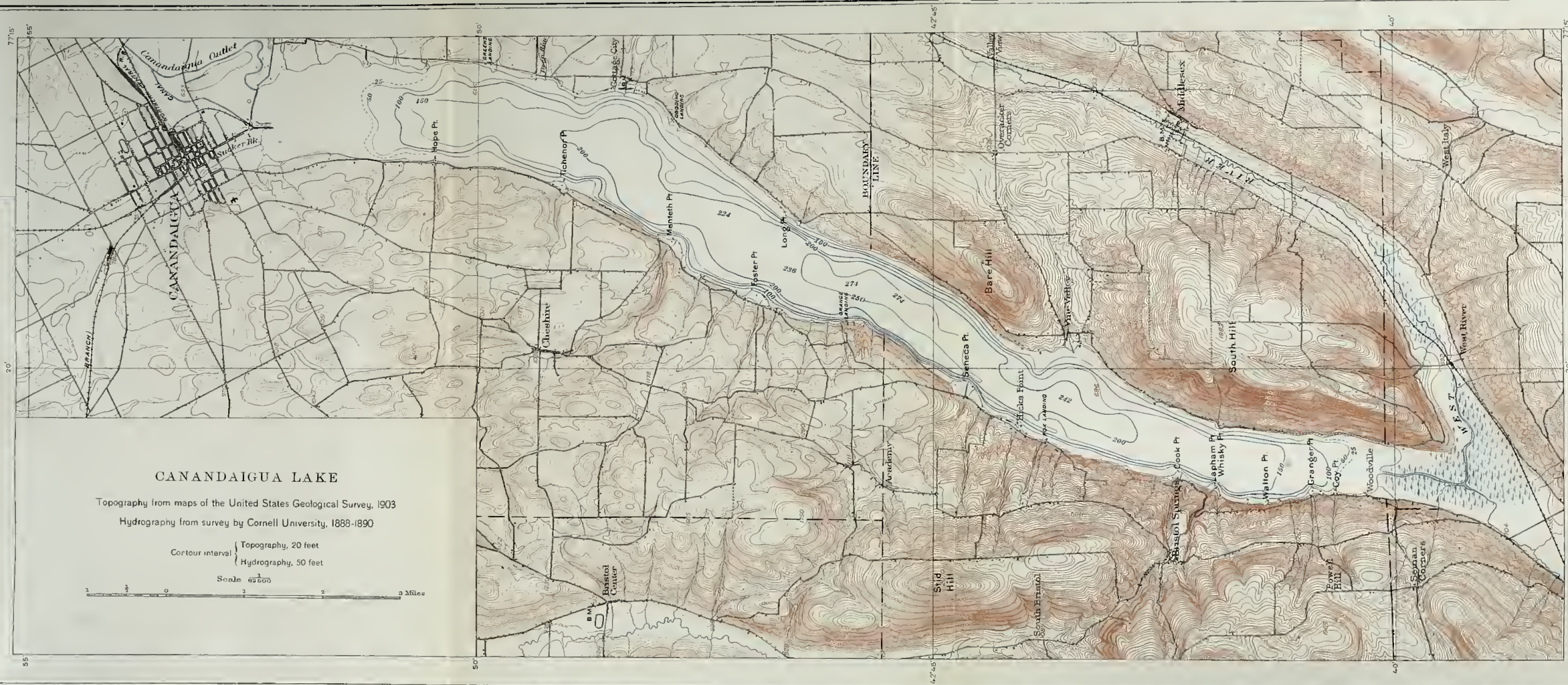
Topography from maps of the United States Geological Survey, 1903

Hydrography from survey by Cornell University, 1888-1890

Contour interval } Topography, 20 feet
 Hydrography, 50 feet

Scale 62500

0 1 2 3 Miles



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